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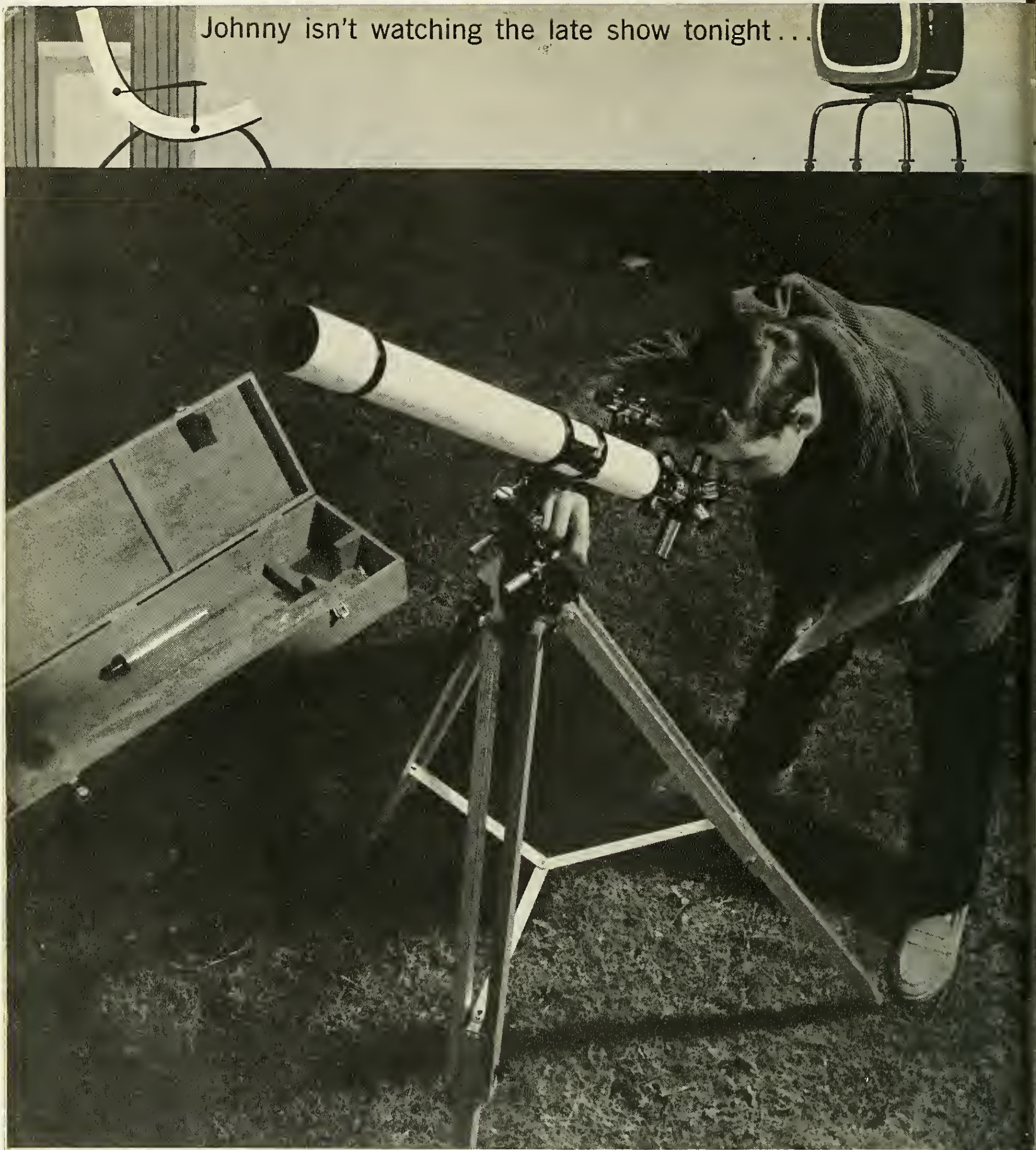
January 1961 • 50¢

Natural History

Incorporating Nature Magazine

Johnny isn't watching the late show tonight...



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Natural History

Incorporating Nature Magazine

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COVER: Magallanes Province of Chile is a desolate land of fiords extending from the southern tip of the Chilean plain to Tierra del Fuego and Cape Horn. Typical of the landscape is this cliff towering over Eyre Channel, into which Eyre Glacier empties. Snow that melts by day refreezes each night into fingers of ice but, surprisingly, the lower rocks are tree covered. In this terrain live the Alakaluf, recent subjects for studies of their unusual ability to withstand frigid weather. Professor Carleton S. Coon, of the University of Pennsylvania, accompanied the expedition and his account of the journey can be found on page 56.

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WASHINGTON NEWSLETTER

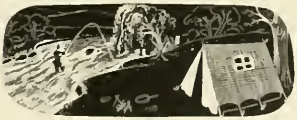
By Richard W. Westwood

WHEN the members of the House went home for biennial fence-mending sks, and most Senators departed with milar aims, the second session of the 6th Congress left behind it a record of ly minor accomplishment in conserva- on legislation. This was, in part, owing lack of time, but even more to an in- fficient inclination to grapple with me issues that might have had contro- rsial significance in an election year. us, all pending legislation will have start from scratch when the 87th ongress convenes this month.

The outstanding conservation enact- ent of the recent Congress was prob- ly the Multiple Use Forestry Bill (now blic Law 86-517), hailed by the De- rtment of Agriculture as "one of the st important pieces of National Forest gislation in the last fifty years." It pre- ribes by law that multiple use and stained yield shall govern the adminis- ation of the National Forests. That is, running our Federal forest program, creation, range, timber, water, and ldlife are recognized as on a par with e another. This is rather like blessing already established union: actually, e United States Forest Service has been administering our forests for many ars. However, it does provide the deral forester with an official blueprint d a bludgeon in case any of these in- rests tends to dominate another.

The Department of Agriculture, rough an unidentified "spokesman," tens to point out that the new law is t a substitute for proposed wilder- ss legislation which the Department pports in principle." It remains to be n whether the law's enactment will be d by some individuals as an argument ainst the necessity of a wilderness asure which, of course, would ap- y not only to our forests but also to e National Parks and the Fish and ildlife Service Refuges.

Other enactments of the 86th Congress luded a provision for co-operation tween base commanders and state conservation agencies in managing public hunting and fishing on U.S. Military Reservations. There has, in the past, been considerable jealousy about prerogatives and responsibilities with respect to such areas. Related in philosophy is another enacted law prescribing protection for forest cover on reservoir areas owned by the U.S. Corps of Engineers—to the end that such forests shall have greater value if used for recreation, for timber-harvesting by sustained yield, and for other conservation purposes. Under another bill, co-operative wildlife-research units of the U.S. Fish and Wildlife Service, other Federal agencies, colleges and universities, state agencies, and nonprofit organizations are given authority in law. Such programs have been in effect for several years. Still another law provides for increased penalties for those convicted of buying or selling migratory waterfowl, thus violating the Migratory Bird Treaty Act.



Armillary Memorial

THE session's closing days were enlivened by a controversy over a local memorial to Theodore Roosevelt. A historic island in the Potomac, across from Georgetown, was acquired many years ago by the Theodore Roosevelt Memorial Association through public subscription. It was renamed for T. R. and has been administered by the National Park Service. It has been kept in a wild state, with access chiefly by boat. Supporting a varied bird life, both migratory and resident, and a population of small mammals, the island has been visited primarily by nature enthusiasts.

With the somewhat surprising acquiescence of the Theodore Roosevelt Memorial Association, a bill was introduced in the 86th Congress, providing for the creation of a memorial that would have as its central feature a great "armillary sphere." That phrase sent some people to the dictionary, but the symbolism of this antique astronomical contraption still remained obscure. There would also have been an imposing approach, parking lots for automobiles, and other features that would have completely "memorialized" the island.

When the plans were revealed, Alice Roosevelt Longworth and Archibald B. Roosevelt, daughter and son of Theodore Roosevelt, and his grandson, Kermit, took violent exception to the proposal. They described it as entirely out of consonance with the thinking of the former President, and they found widespread support among his vast army of admirers, many of whom contended that the island should be left in a "state of nature." Opposition to the bill finally resulted in passage of a substitute proposal, providing that the final selection of any memorial should be subject to the approval of the Roosevelt family.

Pigeonholed

LOST in the final shuffle on Capitol Hill was the most recent of several versions of the Wilderness Bill. Also lost were a proposal to extend the Conservation Reserve of the Soil Bank beyond December 31, 1960, and the Chemical Pesticides Co-ordination Act. This last would have required that any Federal agency planning to undertake a pest control program first consult with the U.S. Fish and Wildlife Service to determine possible impact on wildlife.

The refusal of Congress to increase to $90 million annually (from $45 million) the authorization for grants to municipalities to help construct pollution control plants is regarded by conservationists as specially damaging to progress of pollution control. The Senate also refused to accede to the 1954 London Conference that sought control of oil pollution of the seas. It was feared that, as the World Court was involved, the issue would trigger long debate, and Congress was in no mood for delay.

While Haleakala National Park was created out of a part of Hawaii National Park, other pending park proposals failed. The Chesapeake and Ohio Canal National Historical Park got by the Senate, but did not get to the House floor. Ice Age National Park, in Wisconsin, and Great Basin National Park, in Nevada, got nowhere at all.

Fish and Wildlife

PEERING from the cockpits of bush-pilot planes and spying on the lakes, ponds, marshes, and potholes of the Northwest, Alaska, and Canada, U.S. Fish and Wildlife specialists have checked and rechecked the numbers of geese and ducks in nesting areas this year. On such surveys, plus many field reports and conferences with state authorities, the Service based its recommendations for regulation of the migratory waterfowl hunting season.

Owing to dry conditions, early reports were not reassuring. With more rain in many areas, however, the late hatch was somewhat better. Stringent restrictions during the 1959-60 season cut the waterfowl kill by about forty per cent compared with the 1958-59 season, but there was still a twenty per cent drop in breeders returning north. Conditions on the Pacific Flyway were the most discouraging, and the season was cut there.

Most serious, however, was the situation confronting the redhead and canvasback, the gunners' favorite diving ducks. Given good breeding conditions this year and next, both species are expected to make a comeback, but this year there is a closed season on both. Although duck hunters are loath to admit it, the majority of gunners are unable to identify species on the wing. So, closed season or not, canvasbacks and redheads are falling to the gun again this year. Last year the hunters were allowed one "mistake" if a "can" or a redhead showed up in the bag. Dan Janzen, Director of the Bureau of Sport Fisheries and Wildlife, says that too many gunners made a deliberate "mistake" and more of these birds were shot than should have been.

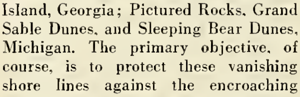
Across the board, restrictions this year again cut the number of shooters. This means the sale of fewer duck stamps, the revenue from which goes mainly for purchase of wintering, breeding, and resting areas in the form of refuges. However, it is unsafe to gamble with this wildlife resource in order to keep stamp revenue at a maximum.

During 1959 there was an increase of 882,000 in the number of those who used National Wildlife refuges. Nearly ten million such visits were recorded, although recreation is still only a by-product of the refuge system. Sixty-three per cent of the users enjoyed photography, picnicking, swimming, and observing nature, while thirty-two per cent fished. Hunting attracted five per cent.

In Oregon, Klamath Marsh serves large numbers of waterfowl on the Pacific Flyway, and is vital to the birds for nesting. Thus, the transfer—by purchase—of 14.641 acres of Klamath Indian tribal lands to the Klamath Forest National Wildlife Refuge is an important development.

National Park Service

ONE long-delayed national park issue that will be actively urged with the arrival of the 87th Congress is that of shore line parks, recreation areas, monuments, or whatever other name may be chosen for them. These include shore line spots along the Atlantic, Gulf, and Pacific coasts, and the Great Lakes. The list embraces Padre Island, Texas; Cape Cod, Massachusetts; Point Reyes and Channel Island, California; Oregon Dunes and Sea Lion Caves, Oregon; Indiana Dunes, Indiana; Cumberland Island, Georgia; Pictured Rocks, Grand Sable Dunes, and Sleeping Bear Dunes, Michigan. The primary objective, of course, is to protect these vanishing shore lines against the encroaching "civilization" that is destined soon to engulf them—a fate that has already overtaken the Indiana Dunes and a good deal of Cape Cod. All of the areas proposed have been intensively studied in surveys financed privately but conducted under the National Park Service.



Individual bills in favor of specific areas were introduced in the 86th Congress but failed to gain headway. A hearing on Padre Island was chiefly to let the opposition be recorded. The National Park Service favored a bill that would have jointly designated Cape Cod, Padre Island, and Oregon Dunes as park areas, apparently on the grounds that these areas deserved first consideration. Individuals had other ideas. Senator Frank E. Moss of Utah, for instance, has prepared a bill for a Great Salt Lake National Park. He is expected to hold hearings in Utah prior to the convening of the new Congress in January.

A drive to create a Cascades National Park—embracing about a million acres of the Oregon Cascades—is gaining momentum. Some of this area is now in wilderness status and much of it is also inaccessible except to the most hardy. The drive is spearheaded by the Sierra Club, and considerable opposition has been generated in Forest Service circles and among those westerners who seem to resent the idea of more National Park areas. This is going to be an interesting campaign to watch. As yet the National Park Service has had nothing to say.

This year the National Park Service observed the fortieth anniversary of its Naturalist and Nature Interpretive Service. This program includes the ranger-naturalist service, nature museums, and other implements for interpreting the natural history of the parks and monuments. Proposed to Stephen T. Mather, first director of the National Park Service, by Charles M. Gothe of Sacramento and the late Mrs. Goethe, these activities have been crowned with success. The program was suggested by similar work observed by the Goethes many years ago in Switzerland.

Within the boundaries of Joshua Tree National Monument in southern California there are 10,200 acres of non-Monument inholdings. There is an imminent threat to the Monument because of projected development and commercialization of these acres. Secretary of the Interior Fred A. Seaton has sought a supplemental appropriation of $1.500.000 to buy these inholdings, but this has not yet been forthcoming.

Another such threat is to Rainbow Bridge National Monument, in Utah, which could be flooded by back waters from the construction of Glen Canyon Dam—part of the Colorado River Storage Project. The law that established this project provided that Rainbow Bridge be protected by diversion dam construction, but Congress has not seen fit to provide money to implement the prescribed protection.

Recreational use of state parks relieves pressure upon National Park areas, and the extent to which this is true is shown in statistics of state park attendance compiled by the National Park Service. In 1959, 255.3 million state park visitors were recorded, an increase of 17.9 million over 1958 and double the total of a decade ago. New York parks had 34.9 million visits, California and Pennsylvania parks, 22.1 million each; Michigan parks, 19.9; Ohio parks, 17.7; Oregon parks, 10.8.

1961 Meetings

FROM March 6 to 8, 1961, the Twenty-sixth North American Wildlife and Natural Resource Conference will be held at the Statler-Hilton Hotel in Washington. This largest annual gathering of conservationists has as its 1961 theme: "Planning for Population Pressures."

Tucson, Arizona, will be the locale of the 8th National Watershed Congress, which is sponsored by twenty-five national conservation organizations. Meetings will be at the New Ramada Inn from April 17 to 19. Field trips will visit Mt. Lemmon, in Coronado National Forest, and the famous watershed exhibit at the Arizona-Sonora Desert Museum.

What's Ahead?

THE new Congress will find conservationists wondering what lies ahead. One thing is certain. New faces on Capitol Hill will mean fresh inquiries as to where these newcomers stand on conservation—indeed, as to what they know about this important issue. Both party platforms in the election campaign took serious cognizance of natural resources and their significance to the nation and its people. But that was only a start. We must wait and see, realizing that the conservation struggle goes on and on

Reviews

recent study of the history and philosophy of modern science

By George Gaylord Simpson

ie Edge of Objectivity, An Essay
the History of Scientific Ideas, by
harles Coulston Gillispie. *Princeton*
niversity Press, $7.50; 562 pp.

ny thoughtful person educated in the twentieth century who dips into cient and medieval learning finds himlf in a world so strange as to be nearly comprehensible. We are told that our ience is the ripe fruit of ancient Greek eds, and on unanimous historical auority we must accept that as true in ne sense. It is, nevertheless, bewilder g to try to define the sense in which same word, "science," could be aped equally in Athens and in Los amos. Many of us today have learned ometry from Euclid, and here the ead of continuity must be most obus. Yet when we turn to Greek mathetics, much of it seems to be mere mber magic; and even the part that st nearly retains validity seems to nsist largely of "proofs" that are not oofs at all in any sensible way, but ly the tautological consequences of ojective propositions to which proof oth inapplicable and irrelevant.

In those elder philosophies that we told to consider as the source of ence, the picture of the world is not ived from that world but from man; from observation, but from logic rating on non-factual premises. Nae is conceived as a reflection of the nan mind and fully endowed with nan emotions. She abhors a vacuum, l one of the reasons is that in a uum motion would be logically imsible. Women naturally have fewer h than man. That proposition established, counting teeth would be unnecesy and also futile, because the subtive deduction is the reality and the ensive observation is only illusion or dent. As late as the seventeenth cen y Galileo struggling to emerge from e ancient world could not persuade antagonists to look through a telepe and see for themselves that their ology was wrong. From their point view, nothing they saw would affect certainties of logic and of authority. The contrast is never more bewilder than when ancient philosopher and dern scientist seem to be dealing with same concept. The Greek atom is at which cannot be cut," a speculative entity, logically deduced from one of two conflicting subjective premises. Has this philosopher's atom really more than the name in common with our atom, egregiously real and disastrously "splittable"? What can truly be common to the subjective "species" as one of the five "predicables" of scholastic logic and the modern, objective species as a group of interbreeding organisms? It is unwarrantably confusing to apply, in retrospect, the one appellation science to two such different ways of attempting to comprehend the universe.

Science in the true sense (in our sense, and therefore semantically true for us) did not arise until nature was viewed as impersonal, until rational induction from observation was given priority over logical deduction from arbitrary premises, and until no aspect of the material universe was granted the privilege of exception to this rationality. This was fully achieved for physics when, in the nineteenth century, James Clerk Maxwell could write of the relationships between theory and observation, that:

"A mature theory, in which physical facts will be physically explained, will be formed by those who, by interrogating nature herself, can obtain the only true solution of the questions which the mathematical theory suggests."

It is an extraordinary fact that science, in this sense, arose but once in the course of history, within one human culture, and over a comparatively short span of time. The culture was that of Western Europe (excluding the Slavic countries and also, significantly, excluding Greece), a culture diverse in detail but with more fundamental unity than divergence. Prominent among the unifying factors were religions ultimately of Judaic origin and philosophies ultimately of Greek origin an oddity in view of the fact that science, the most peculiar product of that culture, was to some degree a rebellion against both. The temporal period involved was, at most, the scant four centuries from Copernicus to Einstein, at least the two centuries from Galileo to Darwin.

It is to that period, approximately the seventeenth through nineteenth centuries, that Gillispie's "essay in the history of scientific ideas" is devoted. Be it said at once that no clearer, sounder, or, insofar as history permits of originality, more original book on the rise of modern science is available. This is not the customary rehash of previous histories or secondary popularization of technical historical monographs. It is a sophisticated, new interpretation based on the essential, original materials: the most influential publications of the historically important scientists themselves. One marvels at the erudition and labor involved in reading so much of the original literature, in comprehending so many branches of science, and in interpreting the essentials for modern readers. Inclusion of some biographical information about the most important figures makes the whole study more interesting and creates a bond of personal sympathy. It also makes clear that science, however objective it may be in the appropriate definition of objectivity, is still the creation of very human individuals. Another point such biography makes plain is that science has national characteristics, here repeatedly exemplified, especially by contrasts between Britain and France.

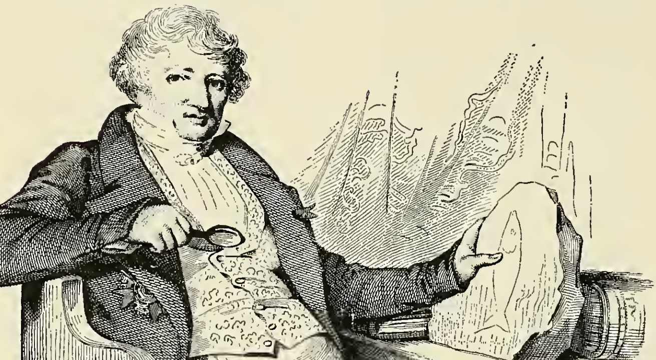
The title of Gillispie's book is somewhat ambiguous, evidently by intention. A dryly academic play on words is an occasional feature of the author's generally brilliant literary style. Thus, the "edge" is sometimes a cutting edge, either anatomizing nature or excising error, and sometimes the boundary of knowledge constantly enlarged by these activities. "Objectivity," for its part, has a special sense, nowhere quite clearly defined but adequately circumscribed, eventually, in the course of the discussion. The subjectivity of many scientific activities and opinions is emphasized. The objectivity of science does not reside there, but in the principles and the approach. It resides in the increasing acceptance of the inviolability of observation, of the absolute requirement for material testability of any hypothesis.

The focus of the author's attention necessarily shifts. Even this rather long book could not adequately treat major episodes without slighting lesser contributions that are not only equally essential

Now an Alexander Agassiz Professor at Harvard, Dr. Simpson has been a frequent contributor to these pages.

but also, in fact and in sum, the greater part of the history. Astronomy is followed only from Copernicus to Newton, for by Newton's day the objective nature of the solar system and of celestial mechanics was fully established and what followed, no matter how important in other respects, was anticlimactic from this particular point of view. Priestley, Lavoisier, and Dalton brought chemistry essentially to the same point of objectivity, and later chemical advances receive only the most casual mention. On that criterion, physics might almost have been dropped with Newton, for he did establish the objective approach in this field. What followed was not so much an increased or broadened acceptance of objectivity in physics as an exploration of where that approach led and of changing *subjective* views as to the implications of its results. Nevertheless, the author does go on to follow those expanding results and shifting philosophies, and wisely so, because this reinforces and further itemizes the theme of objectivity, while also providing a perceptive history of physics through the nineteenth century. (There is a brief twentieth-century epilogue emphasizing Einstein.)

THIS review is written for a special audience, one with some interest in science as a whole but less in physics and chemistry than in astronomy, geology, and, above all, the biological sciences. *The Edge of Objectivity* has been enthusiastically reviewed elsewhere by eminent physical scientists, notably by P. W. Bridgman in *Science*. We may take their word for it that Gillispie's is a major contribution, thoroughly sound, "an extraordinarily good book" as regards physics and chemistry. Astronomy has already been mentioned. Geology here receives short shrift, only twelve pages, but the author previously published a whole book, *Genesis and Geology*, on the crucial period in the history of that science, a book I can highly recommend as even better, within its much more limited scope, than *The Edge of Objectivity.*



GEORGES CUVIER (1769-1832), founder of paleontology.

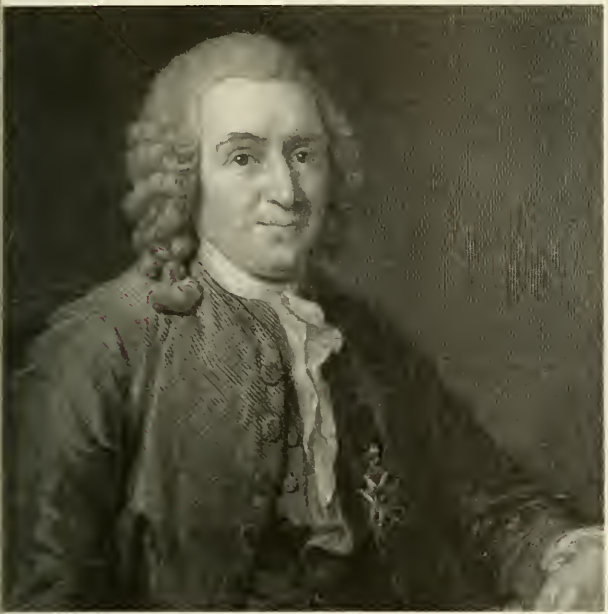
The rest of this review, therefore, I shall devote to Gillispie's treatment of the biological sciences, a topic of great interest to most readers of NATURAL HISTORY but, on the whole, apparently of least interest to the author. It is not that his treatment of biology is grossly inadequate or lacking in flashes of genius. That subject here occupies the greater parts of three chapters and his discussions of Lamarck and Darwin are quite the best available in comparable brevity and far better than the majority of recent, much longer treatments. The trouble is that in this field Gillispie is apparently less receptive, perhaps less informed, and certainly less well rounded than in the physical sciences.

His discussion of biological aspects of the central theme is, indeed, very well related to that theme. This part of the subject centers on Vesalius, who introduced objectivity into anatomy; Harvey, who did the same for physiology; and Darwin, who finally brought the whole of animate nature into the realm of objective science. If this book were *only* about the boundary "edge" of objectivity, and if Gillispie had stopped there, no objection could be made.

However—and most fortunately for the reader—Gillispie is also concerned with the increasing grasp on reality consequent on the objective approach, and with the likewise consequent changing implications and inferences, both scientific and philosophical. As far as physics is concerned, he has taken the space and trouble to explore those broader aspects adequately for the general reader, at least, if not for the specialist. But the implications of objective biology for human life and thought are far more profound than those of physics, and here Gillispie may justly be criticized.

SOME of the most important issues in biology are not even mentioned by Gillispie, although they are extremely pertinent to his theme and fall within the period treated. This is true, for instance, of cell theory—the discovery that all living things have a common organic basis—and of abiogenesis versus biogenesis—whether living organisms can be spontaneously generated or can arise only from living predecessors. Other even more profound, issues are mentioned only to be brushed aside. Examples are the conflicts between vitalism and naturalism and between evolution and religious dogma.

Whatever one may think of the presen status of those conflicts, they did occu in and did profoundly influence the history of human thought. It is not satisfactory for a historian to imply that they were only pseudoproblems or to evaluate them offhandedly and only in term of his own personal beliefs (or prejudices) and of the present time.



LINNAEUS (1707-1778), founder of systematic botany.

Gillispie outspokenly expresses dis-ste for systematics, taxonomy, and ssification. He carries this prejudice en outside the field of biology, for he plies—without sufficient explanation—at what was mistaken in Lavoisier's emistry was the fault of a taxonomic proach. Within the field of biology, llispie's scorn for taxonomy has led n to overlook the facts. This is one of few truly major themes in the history that science; it was one of the main enues of transition from the subjectiv- of creationism to the objectivity of olution; and the complex change from pological to population classification a far more striking and crucial ex-ple of the advancing edge of objec-ty than many he has detailed.

The two nineteenth-century biological bjects that Gillispie does treat with a adness comparable to the scope he nts the physical sciences are evolu-n personified in Lamarck, Cuvier, d Darwin—and heredity personified Nägeli, Weismann, and Mendel. Few dents of biology any longer read La-rck (his style never was attractive), d the cliché "Lamarckism" of modern ts would have been astonishing to La-rck himself. Gillispie clearly sum-rizes the quite different and to us ally astonishing views that Lamarck lly did hold. Gillispie further clari-s the fact (almost universally overlooked elsewhere) that Lamarck's evolutionism was secondary to and derived from his eccentric—one might almost say nonsensical—system of chemistry. A salutary correction of much recent superficial writing on the history of evolutionary theory is supplied: "In no serious sense . . . is Lamarck's theory of evolution to be taken as the scientific prelude to Darwin's."

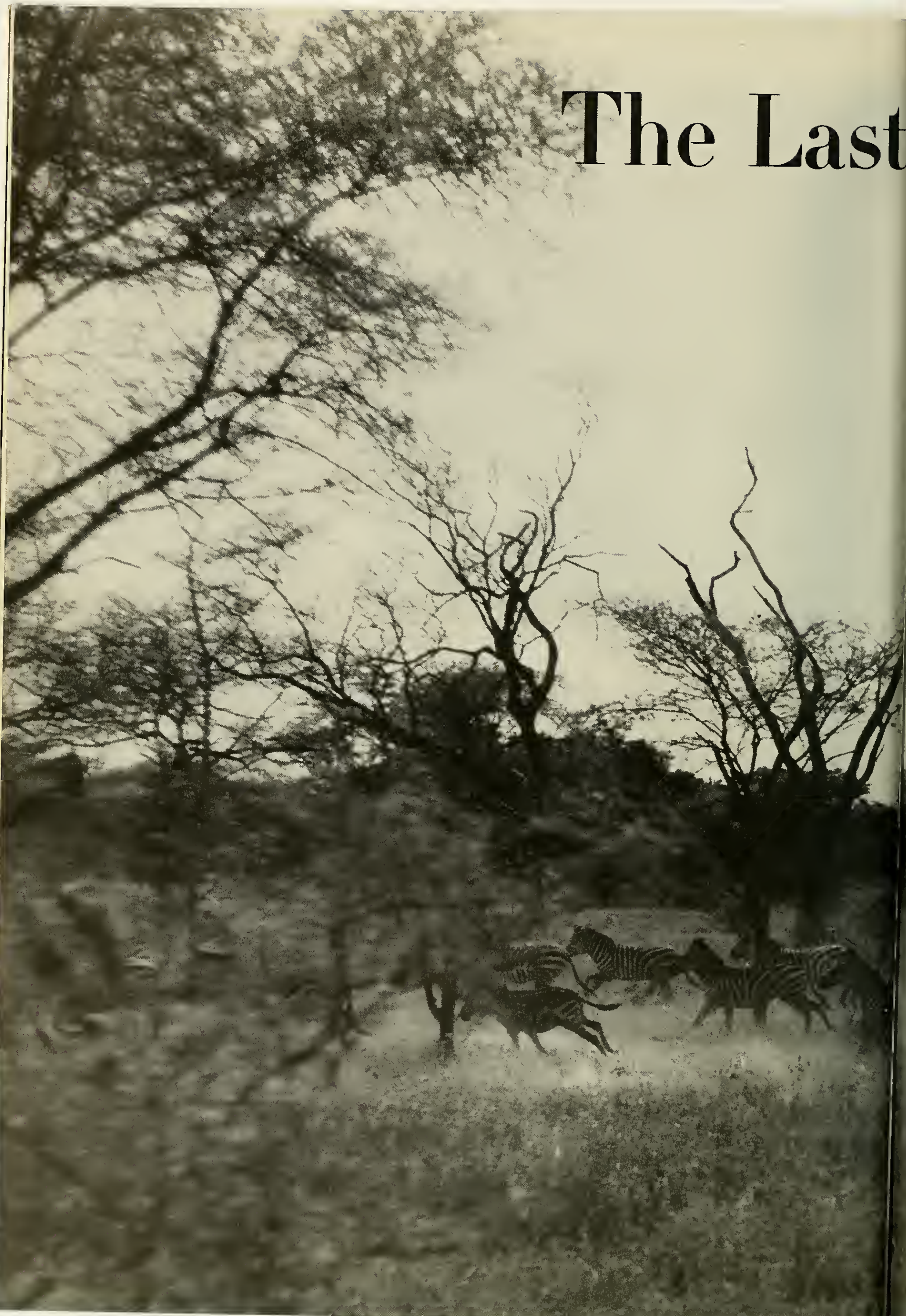
It is unusual to see Cuvier treated at comparatively great length as one of "the founders of evolutionary thought." Cuvier was uncompromisingly anti-evolutionary, and his incomparable authority deeply biased French biology. To this day, Cuvier's dead hand is partly responsible for the fact that no contribution to objective evolutionary theory that was both sound and of first importance has yet come from France. Yet Gillispie's placing of Cuvier in the history of evolutionary theory is right in a different way. Cuvier was probably the most important among the founders of a truly functional comparative anatomy and of an objective recording of the historical, paleontological sequence of organisms on earth. The results of those studies eventually supported and even demanded evolutionary interpretation. Similarly (although Gillispie does not make this point), Linnaeus' rigid hierarchic taxonomy of supposedly divinely created species was an essential preliminary to discovery of how species are created in fact. So in that sense the anti-evolutionary Linnaeus was also a founder of evolutionary thought.

No more need be said about Gillispie on Darwin than that it would be impossible to imagine a better summary of Darwin's life and accomplishment in a brief compass. The treatment of Mendel is appropriately shorter but equally perceptive, and it corrects another cliché: that Mendel's results were not known to his contemporaries. It is, however, impossible to agree that Mendel was to Darwin what Dalton was to Lavoisier, "the one attaching numbers to the other's quantities." Mendel never dreamed of such a thing and had long been in his grave when British and American evolutionists finally perceived the relationship between Mendelism and Darwinism or, rather, between genetics and natural selection. Mendel did establish objectivity in the study of heredity and blazed the trail that is now at last leading to a solution of that age-old enigma. Nägeli and Weissmann, in their different ways, mistook the trail, and discussion of them well illustrates failure to achieve objectivity.

In his review of *The Edge of Objectivity*, Bridgman commented that the author gave unusual attention to biology. It is unfortunately true that this is unusual. University professorships are increasingly being devoted to the philosophy and history of science, and discussions of those subjects are becoming more numerous and more learned. Still, they usually center on the physical sciences, as does *The Edge of Objectivity*. It is regrettably unusual for any general treatise on scientific history or philosophy to treat—as does Gillispie—even two aspects of biology adequately. Perhaps it is symptomatic of this to find Gillispie saying that "Nordenskjold's *The History of Biology* . . . must still serve as the best general history of the science." For Nordenskjold's history is not only seriously out of date but also dully pedestrian, lacking in insight, and so biased that it closes with a denial of the most important advance ever made in biological theory. We must, then, be grateful to Gillispie in that he does cover some aspects of the history of biology excellently; but the coverage is still not adequate or wholly free of bias.

This is a work in which abstruse subjects and complex ideas are expounded in elegant but undiluted language. It is no book for the completely uninformed in science or for those who seek only a superficial orientation. It is, nevertheless, accessible to the serious amateur and for him will prove far more profitable—and, eventually, fascinating than the more usual, journalistic popularizations.

The Last



Great Herds of Africa

An aerial census of animals in the Serengeti National Park

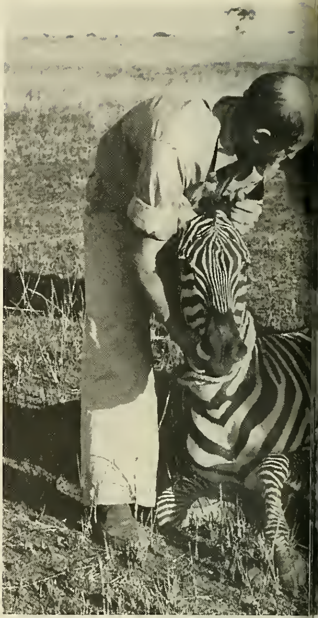
By BERNHARD GRZIMEK

THE NATIVE CHIEFS in Tanganyika co-operated in a population cen-us several decades ago by turning ver to authorities a variety of seeds epresenting their subjects. Long grass eeds represented boys; little round eeds indicated girls; thick black seeds mbolized men; and brown seeds epresented women. The system was mple but effective. No such enviable simplicity was possible for myself and my late son, Michael, when in 1957 we were asked to make a census of large animals in the Serengeti National Park in Tanganyika, British East Africa. Colonel Peter Molloy, then director of the National Parks of Tanganyika, requested the survey to determine accurately the extent of the animals' seasonal movements.

The Serengeti Park, which is the only national park in Tanganyika, was established for the protection of great plains animal herds and their environment. The enormity of the task that faced us may be imagined in view of the size of the park—4,600 square miles—and the erroneous belief at the time that it sheltered some million animals or more within its borders.

Zebra flees from rope noose handled by man riding on roof of pursuing car.

Animals had to be caught for marking so herds could be identified from air.



Author's son Michael, *right*, swabs dye on rump of immobilized zebra. The

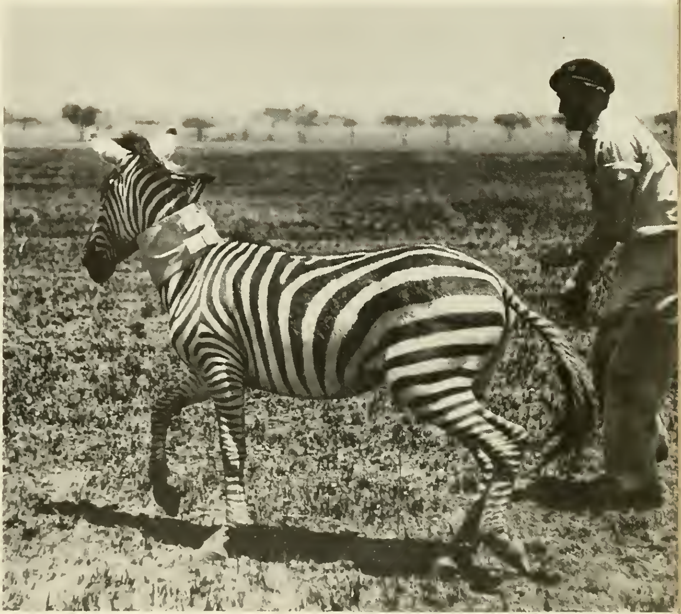
Motivating the census was a government plan to reduce the size of the park and to alter the boundaries in favor of Masai tribesmen. The action was to be taken in connection with recommendations set forth in an official study made in 1957. However, this study, in regard to movements of large herds of plains animals including wildebeest (or gnu), zebra, and Thomson's and Grant's gazelles, had necessarily been based on assumptions by others and on brief observations. The census we had been asked to make was to be of particular importance, since the herds of Serengeti are presumably the last great herds of wild animals still surviving in Africa.

The immediate concerns of our census were twofold—both to establish the number of animals in the Serengeti National Park, and to discover whether the herds were actually protected by the current park boundaries and would continue to be protected by the proposed new boundaries. In view of the great area to be covered and the terrain involved, a survey by motor vehicle was impractical. Because the plain areas in Serengeti, and much of the mountainous part as well, are devoid of trees, we decided to count the animals from an airplane.

To accomplish this project, my son and I both learned to fly a plane. In December of 1957, we began a 6,000-mile flight from Germany to equatorial Africa in a single engine Dornier 27. The Dornier, a refinement of the World War II Fieseler *Storch* observation plane, had been selected for the job because of the excellent visibility from its cockpit. An additional advantage of this craft was its ability to fly at very low speeds. In fact, it could remain aloft at just thirty miles an hour, which would be invaluable for making observations and would also permit the plane to operate from almost any flat area without being dependent on airfields and landing strips. The plane was painted with bold "zebra" stripes to make it easy to spot in case we were forced down.

Our original intention was to fly over the whole park area, photographing it with automatic cameras. However, we discovered that it would be necessary to fly at very low altitudes, about 2,400 feet, in order to identify reliably the different species recorded on the film. Our calculations, based on

resulting yellow stain was not durable enough, so the process was abandoned.



Plastic collar on zebra, released to rejoin herd, solved problem of marking animals. Brightly colored material was easy to see from air and lasted months.

the results of previous aerial surveys y other workers, showed that, at that ltitude, we would have to make more han 50,000 vertical exposures to over the whole area. Economically, uch a procedure was out of the ques- ion. Further, the absence of landmarks in much of the area to be overed would have made it impossible o join individual oblique photographs f adjacent areas. Our solution was to divide the area of the park into dis- ricts, or zones, and to fly over each of these in parallel sweeps, counting he animals of various types included within a specific angle of vision to ach side of the plane.

In establishing these zones, we tried o take into consideration natural bar- iers—such as river valleys and moun- ain ranges—so that animals would not e able to shift easily from counted nto uncounted districts, thus upset- ing our totals. Test flights indicated hat a 150-yard-wide strip to each side f the plane could be observed accu- ately. The plane would have to fly at a height between 150 and 300 feet. Results of the tests showed that an bserver could distinguish easily be- ween antelope species and even classify them as adults or young at a distance of 1,500 feet. In areas where there were few animals and where scanning was easy, the strips were extended in width to 2,000 feet.

In flight the pilot navigated, and his was the responsibility of establishing the width of the strips and the sequence in which they were to be surveyed. The task was complicated by the absence of adequate maps for the area. The park had to be covered on the basis of incomplete sketches in which only large streams, rivers, parts of mountains, and a few pastures were shown. Flight courses had to be set using landmarks such as lone trees, rock outcroppings, water holes, and clusters of bushes. Sweeps were made by following compass courses almost exclusively in an east-west direction or the reverse. This heading was chosen to minimize drift: a strong easterly wind blew constantly during the whole survey period. While flying over a strip, the pilot would note landmarks along one edge to be used as guides for the edges of the adjacent strip to be surveyed on the next pass.

One thought we needed to consider about our aerial survey work was the reactions of various animals to the presence of the airplane. In practice, the reactions appeared to vary quite as much as the wildlife itself, and seemed to depend on many factors. Generally, lone animals reacted little to the plane overhead, even when it flew as low as thirty to sixty feet. This held true for both Thomson's and Grant's gazelles and also for zebras, kongonis, and topis. In fact, resting Thomson's gazelles did not even bother to stand up when the plane passed sixty feet above them. Small herds of from five to fifteen zebras or antelopes would run about one hundred yards from the plane's path, often dashing across its line of flight. They exhibit the same tendency to dash across the paths of autos in the

Dr. Grzimek, the Director of the Frankfurt Zoo, and his son Michael are co-authors of *Serengeti Shall Not Die*, to be published soon by Dutton. Michael died in an airplane crash toward the end of their study. *The Journal of Wildlife Management* has published some of the findings that Dr. Grzimek presents in this article.

Needle-tipped bullets for "miracle" gun were difficult to prepare. Weapon was used to anesthetize wild animals, but was unreliable before modification.

Serengeti. Larger herds of fifty or more animals reacted rather differently. Gnus especially, were very nervous. They would begin to race away even when the aircraft was at a height of six hundred feet, although lone specimens did not react at all. It seemed that a few particularly skittish animals would trigger escape reactions in a herd, and others would follow suit.

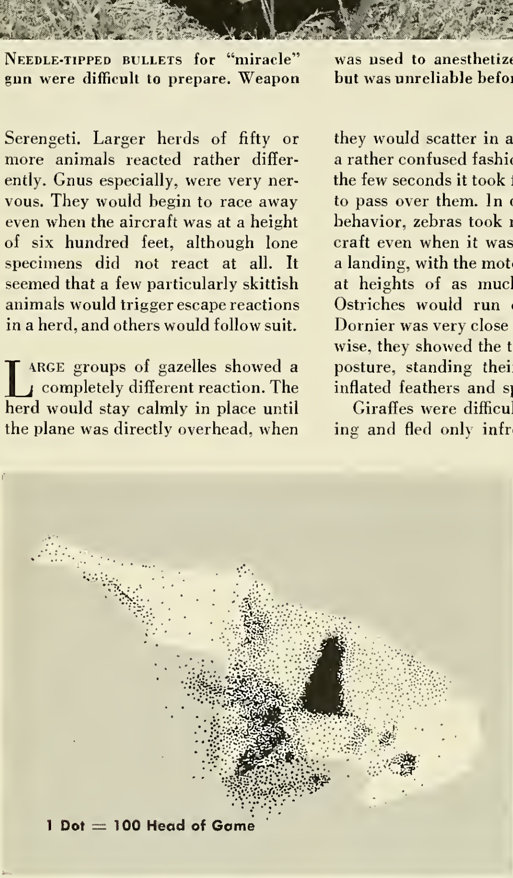
Large groups of gazelles showed a completely different reaction. The herd would stay calmly in place until the plane was directly overhead, when they would scatter in all directions in a rather confused fashion, but only for the few seconds it took for the airplane to pass over them. In contrast to this behavior, zebras took note of the aircraft even when it was gliding in for a landing, with the motor switched off, at heights of as much as 150 feet. Ostriches would run only when the Dornier was very close to them. Otherwise, they showed the typical "threat" posture, standing their ground with inflated feathers and spread wings.

Giraffes were difficult to start moving and fled only infrequently. Even then, they would run only 150 feet or so to the side. If they were standing beneath trees they did not bother to move at all. Baboons would always run immediately to nearby trees.

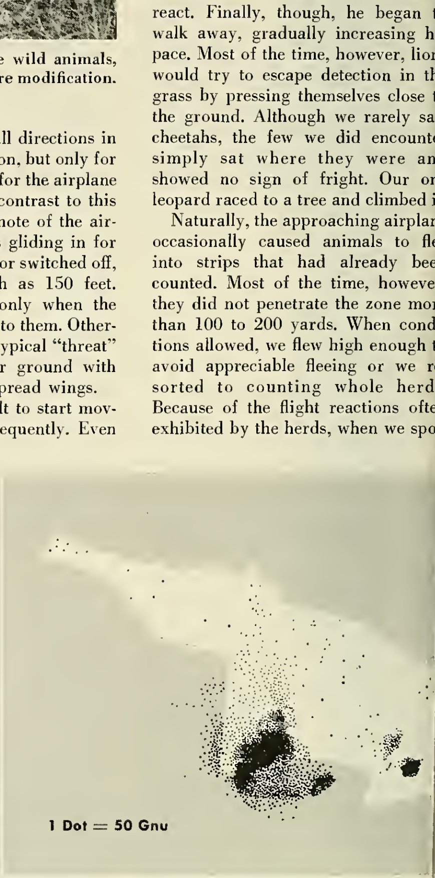
Although hyenas with prey fled while the plane was still some way off, specimens sleeping near a water hole could not be chased away. In extreme cases they might wake up, stand, and take a long look at the plane that was disturbing them. On the other hand, wart hogs fled promptly, and on one occasion, a wart hog was spotted taking cover in a nearby burrow.

Lions reacted in various ways. In the Ngorongoro Crater, we flew over and circled about an adult male. At first he showed little inclination to react. Finally, though, he began to walk away, gradually increasing his pace. Most of the time, however, lions would try to escape detection in the grass by pressing themselves close to the ground. Although we rarely saw cheetahs, the few we did encounte simply sat where they were an showed no sign of fright. Our on leopard raced to a tree and climbed it

Naturally, the approaching airplan occasionally caused animals to fle into strips that had already bee counted. Most of the time, however they did not penetrate the zone mor than 100 to 200 yards. When conditions allowed, we flew high enough t avoid appreciable fleeing or we resorted to counting whole herds Because of the flight reactions ofte exhibited by the herds, when we spot



General distribution of wildlife in the Serengeti Park shows central concentration, plus migration over boundaries.



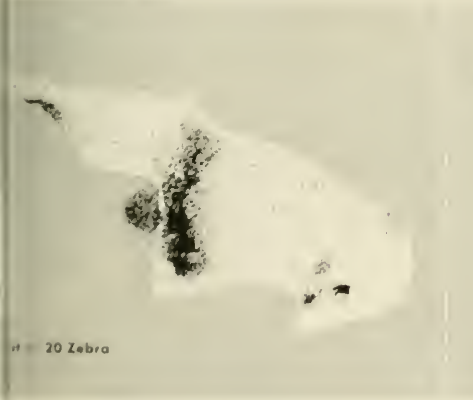
Large gnu population clusters near southern perimeter the park. Gnu are noticeably absent from northern secto

STILL STUPEFIED by narcotic from the "miracle" gun, Thomson's gazelle buck, *left,* is ear-tagged by Michael. When the effects of drug began to wear off, *above,* Michael and assistant had to be more wary of the active little animal.

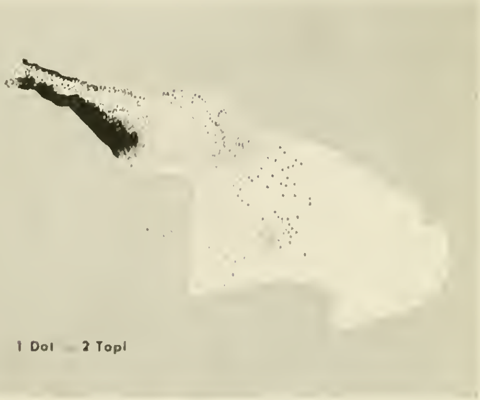
ed one we would gain altitude in rder not to spook the animals into ı previously surveyed strip. Then we ould circle and count the herd without disturbing it, disregarding comletely the boundaries of the strips.

Of course, the problem of how to dentify herds that had already been ounted was one that arose. This was n important question not only beause we did not wish to upset the ensus by re-counting the same anina s but also because we wanted to e able to trace herd movements from ne part of the park to another, and further, to see if these herds were straying outside of the park's present and proposed boundaries.

TRADITIONAL methods of marking animals include dyeing or painting their hides, and putting metal clips in their ears. For our purposes, metal clips would be useless since they could not be seen from the air. Dyeing would not work at all on animals whose hair was black, and would not work well on animals with greasy hair. In any case, it was probable that neither dye nor paint had sufficient permanence and durability to mark these animals for the length of time we thought desirable. We finally settled on marking individual animals in the herds with brightly colored, plastic collars. The brilliant color of these collars was easily distinguished from the air. Made of several layers of synthetic material, they were also quite durable, and the smooth finish meant they would not irritate the animals that wore them. At first, we were concerned about the reception a marked animal might receive from others in his herd. Fortunately, the marked animals



[illegible] ZEBRA leave protection of preserve area near the ntral western edge. More than 57,000 zebra were tallied.



MAJORITY OF TOPI were found in northern portion of the Serengeti preserve. Most dense grouping was along border.

Gnu runs at top speed, *above*, in an attempt to escape low-flying airplane.

seemed to be treated normally by their companions. The durability of the collars was proved by the fact that eighteen months after we had banded some animals, they were seen in the park still wearing their gay bands.

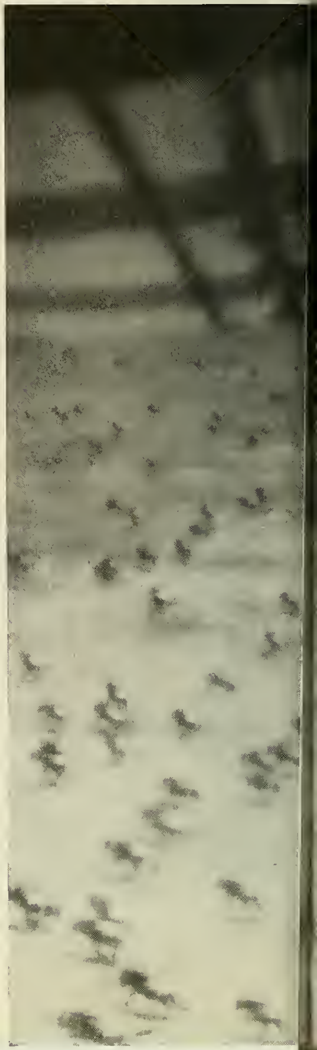
Putting collars on wild animals, however, is in one respect analogous to the classic recipe for rabbit stew that says to, first, catch the rabbit. In our case, we had to, first, catch our wild animal. This was no mean task. We had heard a great deal about a "miracle" gun manufactured in the United States, which shot a projectile containing drugs. In theory, hitting an animal with one of the needle-tipped bullets injected a narcotic and anesthetized the animal so that it might be approached safely.

We acquired one of the guns in the hopes that it would fulfill our requirements. The weapon was powered by compressed carbon dioxide, a puff of which shot the hypodermic-type projectile between sixty and one hundred feet. Behind the plunger of the projectile was a mixture of carbide and water, which produced gas to drive the plunger forward, injecting the narcotic solution into the target animal. Our first results with the device were rather disappointing.

For one, it was relatively inaccurate, and we could never be sure just how far the bullet would carry. Secondly, even when an animal was hit squarely, the performance of the bullets was erratic. Thirdly, the syringe projectiles were slow to use. The narcotic solution and the carbide and water mixture had to be loaded in the field immediately before firing. Clearly, we had to remodel the contraption to adapt it to our needs.

During a return to Frankfurt, Michael modified the weapon and tested it. The new power source was compressed air at a pressure of nearly three thousand pounds per square inch. Effective range of the weapon rose to 120 feet with reasonable accuracy. The hypodermic bullets were also modified so that the impact of hitting the target was sufficient to drive home the plunger. This meant that a supply of the darts could now be loaded in camp and taken, ready to use, into the field. It also assured that the animal would receive the full dose in the bullet, whereas, with the previous system, only a partial dose was administered as often as not.

Finding the correct anesthetic for use on various animals proved a more difficult problem, and this took many months to resolve. The toler-



Hundreds of gnu race across a veld, their usual reaction to plane's sound.

ances of different animals to a given drug varied greatly, and often, surprisingly. For example, a gnu shot with a dose per pound body weight less than that tolerated by an ordinary domestic goat was incapacitated overnight, during which time we had to watch him to see that he was unharmed by predators. However, the proper dose per pound body weight for gnus of the drug (nicotine salicylate) had no apparent effect on little Thomson's gazelles. We finally learned that they required a dose per pound five times as large as that used for the gnus. We also found that the Thomson's gazelle bucks had to be captured while lying down. While running at their speed of about thirty miles per hour, the slight effects of the drug disappeared.

ONCE correct dosages were ascertained for the various animals we wished to mark, the actual collaring became much simpler. The drugged animal could be approached and the plastic collar fitted to its throat. In a matter of minutes, the beast would regain its feet and, soon after that, would rejoin its companions. Only the zebras would never let us come close enough to use the "miracle" gun.

Zebras required an entirely different, more energetic—and dangerous—approach. In the beginning, when we had tried dyeing them with picric acid, we would chase them by car, while a member of our group sat on top of the vehicle holding a long pole with a rope noose at one end. By isolating one animal from its herd, then driving alongside it, always keeping parallel to its line of flight, it would be possible to close the range until the man with the pole could slip the noose over the tiring animal's neck. The danger lay in the precarious position of the man with the noose, who had to handle the unwieldly pole while trying to maintain his seat on the roof of the bucking, swaying car. On one occasion,

Michael was handling the pole when a lurch of the car caused the tip of the pole to catch in the ground. Immediately, the rear of the pole rammed back and hit Michael's throat, inflicting a serious wound that necessitated flying him to a hospital for an emergency operation. Despite this experience, Michael insisted upon rejoining the group almost immediately.

Later we modified this method for catching our zebras. We would race in the car alongside an animal and whoever was best located would reach out and grab the animal's tail. Naturally, this is much easier said than done, and it might be noted that a zebra's tail does not afford the most secure grip desirable under the circumstances. Despite the obvious difficulties involved, we became quite proficient at this method of capturing zebra. After subduing the animal, we would fit it with a collar and let it rejoin its herd.

Sad to say, one of the greatest threats to the safety of animals in Serengeti is posed by man himself. We were made painfully aware of this during a flight undertaken for the sheer joy of flying on a beautiful day. High above the plains spread below, Michael cut the motor of the plane and we glided in silence through the clear air. As we descended, a fine line across the ground caught our attention. Gliding still lower, we saw that the line was a fence of twigs and thorny branches punctuated by occasional gaps. The fence had been raised by native poachers, who slaughtered herds for meat and to provide the souvenir and curio market with teeth, hoofs, hides, and horns of various beasts. In the gaps of the fence were wire snares that would entangle any animal trying to pass through. These fences were generally placed to intersect a migration route or trail commonly used by the herds.

The poachers were still near the fence and, as Michael touched the starter button and the engine roared to life, they dropped to the ground.

Ve buzzed them in an effort to drive hem away and. during one pass, some f them dropped to their knees and et fly at the airplane with poisoned rrows. From the safety of the cockpit heir gesture appeared futile. but when e landed at our base some time later e saw an arrow protruding from the netal wing of the plane.

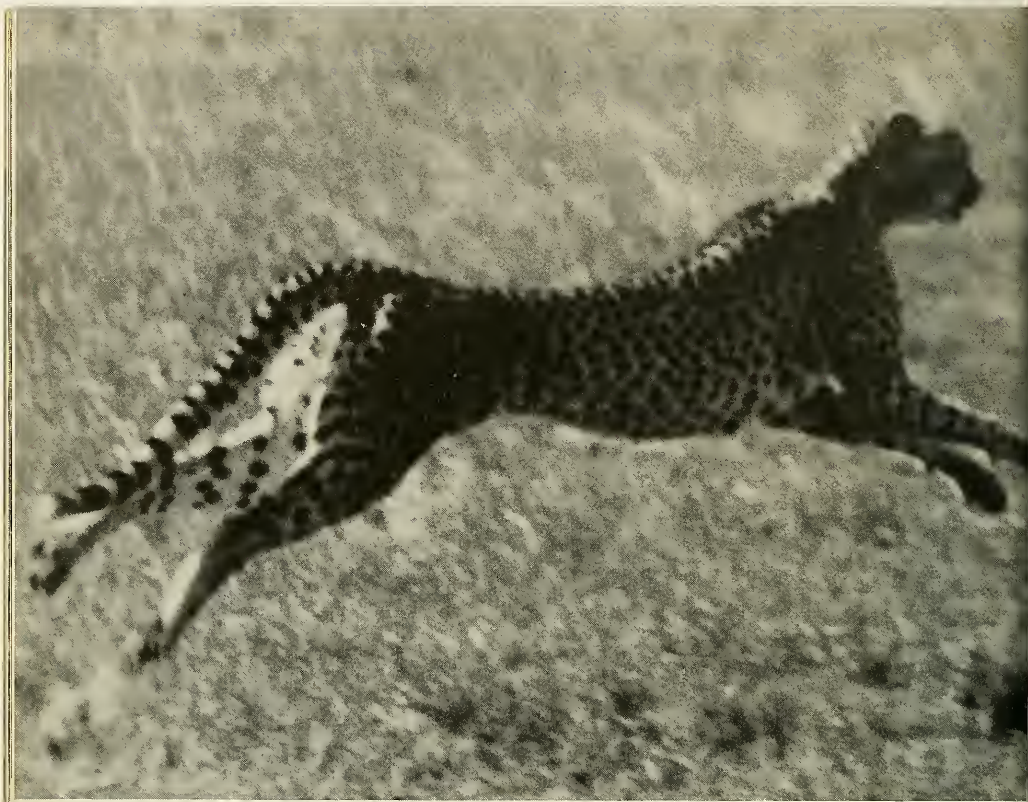
Aside from the obvious objections o the poachers' depredations against protected" animals. we were infuri- ted both by the cruelty of the methods sed, as well as by the enormous waste f the animals so slaughtered. When naking auto trips where poachers had een at work, we often came across nimals that had died by slow strangulation in wire nooses, or had been trapped in the snares and then dispatched by predatory animals. Often the victims would decay before the poachers arrived to take the meat. Occasionally an animal would be found minus its horns or paws. the only parts that the poachers wanted.

Giraffes, *left*, seldom ran from the plane. Census showed 837 in Serengeti.

Paced by car, ostrich ran more than twenty minutes at thirty miles an hour.

Eventually our indignation mounted to the point where we took part in a raid against a group of poachers. Two of the band were caught. and they naturally claimed that they had merely blundered into the poachers' camp. The camp itself, located in a small clearing within a wood might have served as the backdrop for a scene from a Grand Guignol performance. Wherever one looked there were strips of raw meat hung to dry from poles arranged to form racks. The sunlight shining through the gory slabs gave a bloody, eerie glow to the camp. Tangible benefits of the raid included the capture of three truckloads of bows, poisoned arrows, and wire snares, all of which were destroyed or tossed into a pit too deep to permit retrieval of them.

Unfortunately, both American and European tourists also complicate the situation through their hunting trips. It is not entirely reasonable to expect natives to accept the idea of being punished for hunting when they see the hunting parties of wealthy visitors roll through their villages in cars loaded with trophy animals. Furthermore most African governments have



RUNNING AT FULL SPEED, cheetah is caught in mid-stride by camera. Reputed to be the fastest of all animals, cats usually prey on Thomson's gazelles, which can run at least as fast as thirty-seven miles an hour when on level ground.

diminished the value of preserves and parks by not appropriating sufficient funds to ensure that the animals in them are guarded adequately.

Before discussing the results of our aerial survey, it is desirable to pause to consider some of the sources of error inherent in making a game census under such unusual conditions. One factor that presumably could never be eliminated was the natural movement of animals from a counted strip to an uncounted one. The reverse situation also may have been encountered. We tried to minimize this problem by covering in one day areas that had no natural barriers separating them. In general, we tried to count consecutively adjoining areas.

Another possible source of error lay in the blind spot directly beneath the fuselage of our airplane. Mitigating this factor were the predominantly low altitudes at which we flew, which minimized the actual hidden area. Besides, most of the animals counted scattered to the side, out of this zone, so this was most likely not a major source of error.

More important perhaps were the long distances involved in flying to the study areas. Because of this, it was often necessary to count for more than two and one half hours at a time, a chore that led inevitably to exhaustion on the part of the counters and of the pilot, who had to rest for several hours after each trip.

THE position of the sun also affected our counting. Because the strips to be surveyed were oriented principally in an east–west direction, at certain times of the day sweeps in one direction or the other might be made directly into the sun. We noticed, for example, that we sighted fewer gazelles when flying toward the sun than when flying in the opposite direction. The amount of error this produced varied depending on the species being counted. More conspicuous animals, such as giraffes and rhinoceros, could hardly be overlooked. They could be seen at great distances and it was not likely that they might be missed. For the giraffe, rhinoceros, elephant, oryx, roan antelope, and probably for buffalo, our figures were likely to be very accurate. Elephants, rhinoceros, and buffalo occurring in rain forests, however were not included, because they could not be seen from the air. It is also possible that there might have been some errors in the counts of larger herds of gnus, zebras, and gazelles especially considering that some herds of two thousand or more were observed during our census flights.

In summary, while it is possibl that a margin of error of twenty pe cent exists in the total number of animals we counted, the error should certainly not exceed that figure.

Lowering head, a rhinoceros in the Ngorongoro Crater prepares to charge the author, who wanted to see how the animal would react to approach by man.

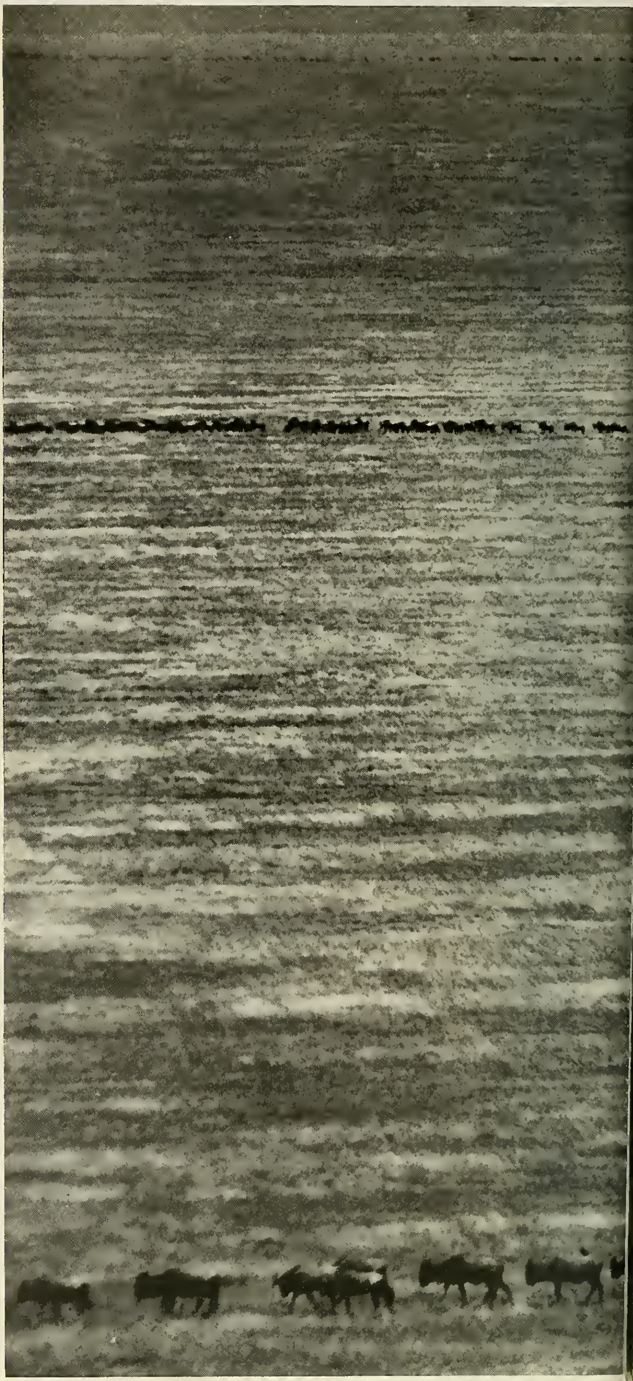
Kicking up dust, a wart hog pounds across road in path of Grzimeks' car. When threatened, wart hogs have been known to turn and charge at elephants.

THE survey results were not entirely surprising to us. Prelimi-ary counts had shown that the move-ents of several species were not mited by park boundaries. During ome seasons, a great many animals ave the area of the park. However, e total count of large animals proved be 366,980, or only a third of the umber popularly estimated for this egion. Regarding distribution of the nimals, our findings raised a whole ries of new questions.

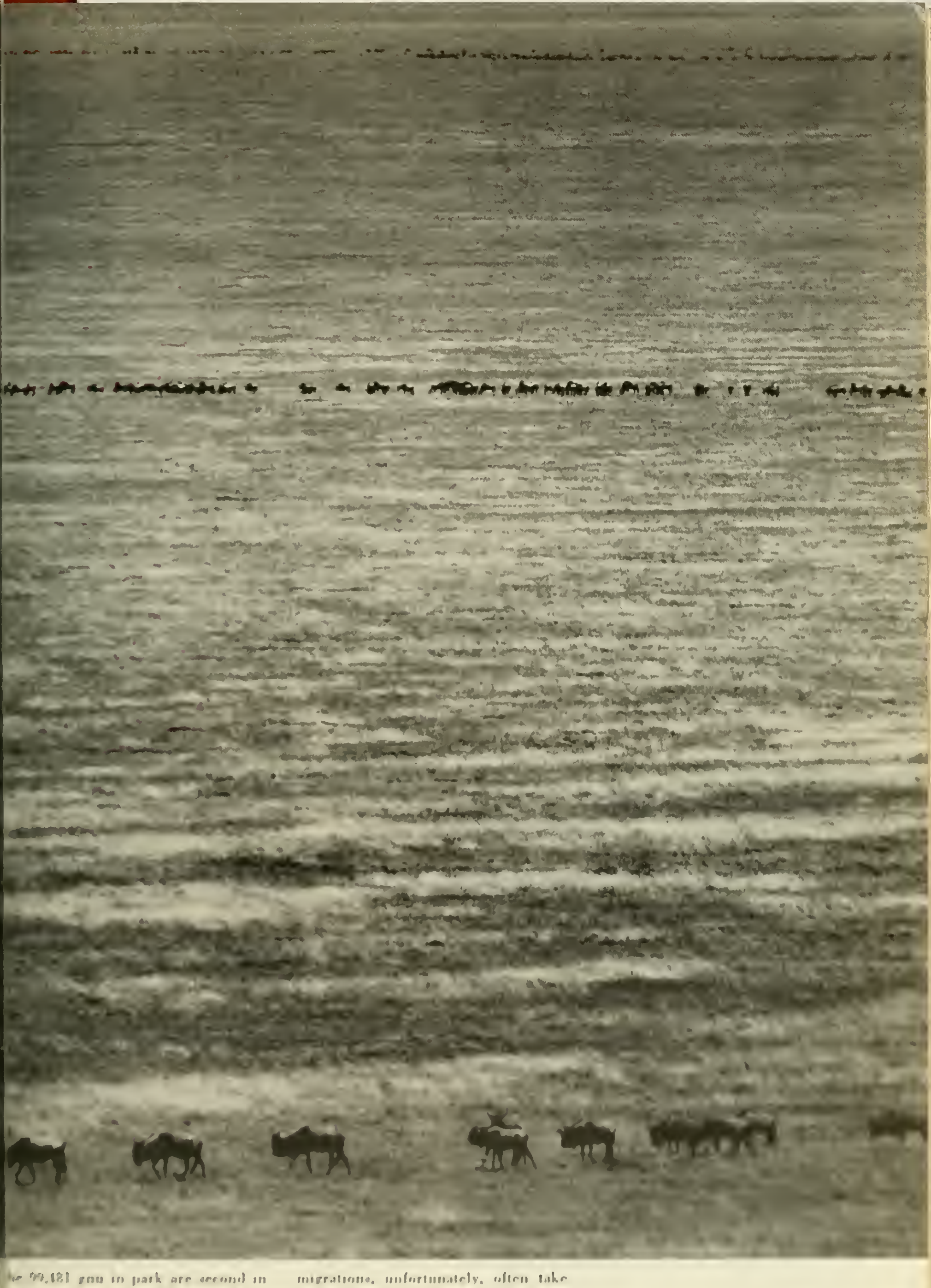
Animals of a given species are not niformly distributed over the entire rea of the Serengeti Park but tend form concentrations in certain laces, while in other areas they may e entirely absent (see maps, pp. 12-3). Regarding giraffes, the reason is vident—they stay among trees or near em. Waterbucks were found only ong riversides or in parts of the gorongoro Crater. Impala occurred ly in heavy bush and tree plains areas and were not seen on open plains. This also applied to the topi, but less strictly so. As to gazelles, the interpretation is more complicated, and the same is true for gnus. It is possible that soil types and, indirectly, the composition of the vegetation play a part. Gazelles could also be pushed from an area into a region with poor vegetation by population pressure of the closely associated gnus. Generally, the way in which one species fits into the openings left by other animal groups was conspicuous.

THE upsetting fact that emerged from our survey was that every year the large herds moved far beyond the new borders proposed for the park. They remain outside this area for many months. We wanted to find out why. Michael landed in many different spots in the Serengeti to study the vegetation and take samples for analysis of the types eaten by the game and those spurned by them. The results of his research indicate that the preferred type of grazing grows, to a great extent, outside the future limits of the park during the rainy season. What grows within the future Serengeti is considered largely inedible by the animals during parts of the year. We have studied the nutritive content of the grasses and have tried soil analysis to find the reasons for the difference in distribution of various grasses. We concluded that the herds need the area that is to be taken away. Ironically, the land in the park—adequate for wild animals—would be inadequate to support the Masai's overly large herds of cattle. The big wild herds move over the central part of the Serengeti Plains in the rainy season in large circles, always returning to the same place periodically. The situation is like that on a modern dairy farm, where cows are driven daily to new areas, returning every few days to the same spots, eating only short, protein-rich grass.

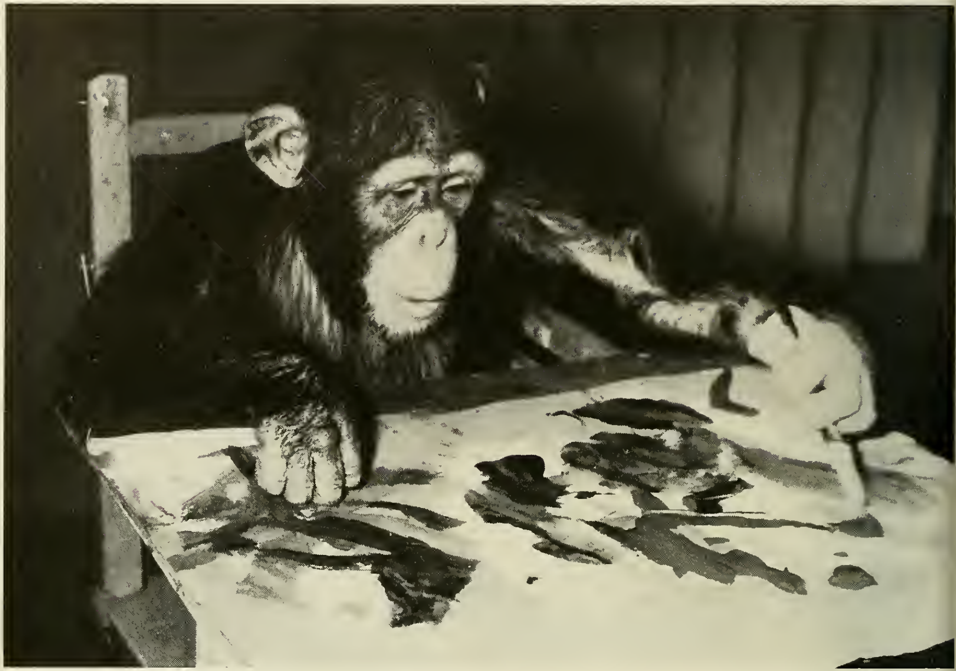
In surrounding districts we saw that large herds of cattle—protected against infectious diseases—cause soil erosion and can, in a few decades, change the land to desert. In contrast, wild herds live in a natural balance with the vegetation. Because the land around the Serengeti is more heavily settled by natives each year, I believe that if the new boundaries remain in effect, large parts of the great wild herds must surely die.



THREE HERDS OF GNU cross plains o
Serengeti in typical migration lines



he 99,481 gnu in park are second in umber only to the park's gazelles. Gnu migrations, unfortunately, often take them beyond boundary of preserve.



Artistic ape, Congo slashes bold stroke of color across one of his works, holding brush in "sophisticated" manner.

Dr. Morris and subject strike relaxed poses during a lull in experiments probing the biological origins of aesthetics.

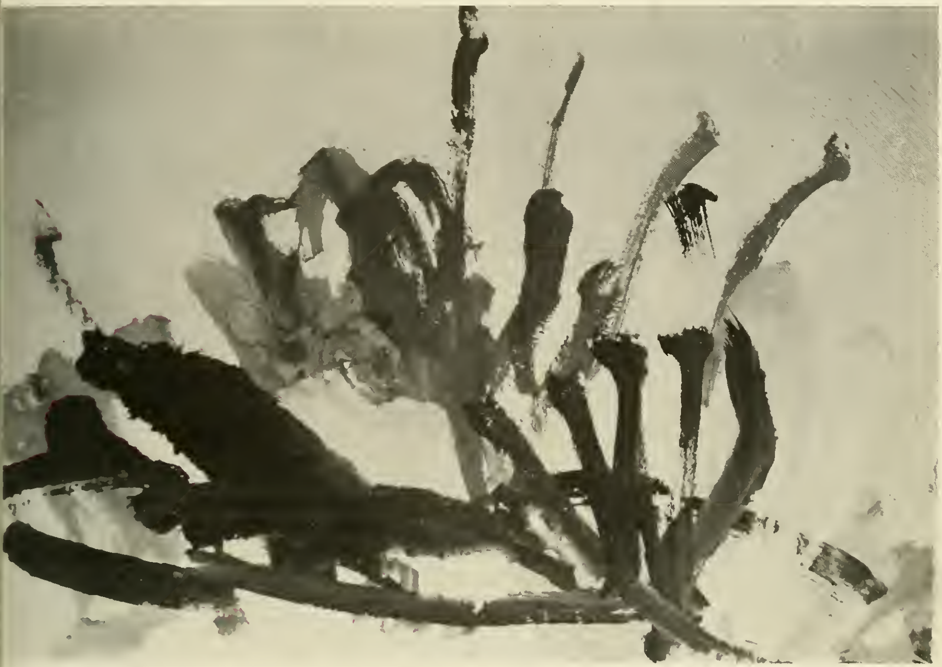
Primate's

An ape provides clues to the

By Desmond Morris

A journalist once asked Picasso for his opinion of paintings produced by chimpanzees. The artist's response was characteristically original. He bit the reporter. The picture-making chimpanzees have also been known to treat their interviewers in a similar manner. Human and chimpanzee painters do, however, have other, academically rather more interesting, similarities. Just what these are when the emphasis shifts from drawing blood to drawing pictures, will, I hope, emerge from the following report

Man has always been interested in the origins of his artistic activities and several sources of material have been probed in recent years in the hope of finding some of the answers. But these sources have not been as illuminating as was once hoped. Prehistoric picture-making, left to u in the form of cave-wall remnants, has proved far too advanced an art form to tell us much about the way it al began. Also, the present-day art of so-called primitiv peoples has finally emerged as anything but primitive. I is only in the realm of child art that we have been abl



Unusual painting by Congo is remarkable for presence of principal design plus subsidiary fan pattern at lower right.

aesthetics

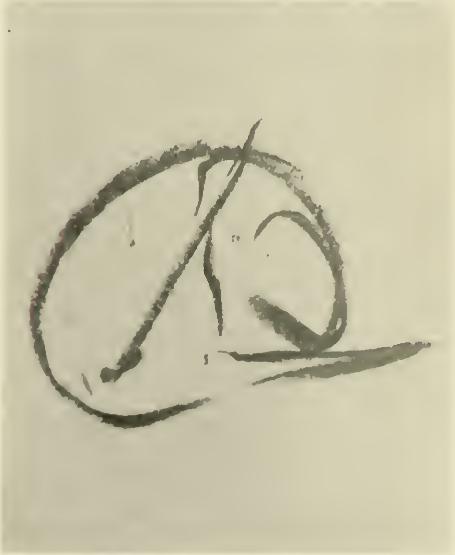
rigins of artistic activities

find any clues, and even in this area the influences of rents and teachers cloud the issue all too soon.

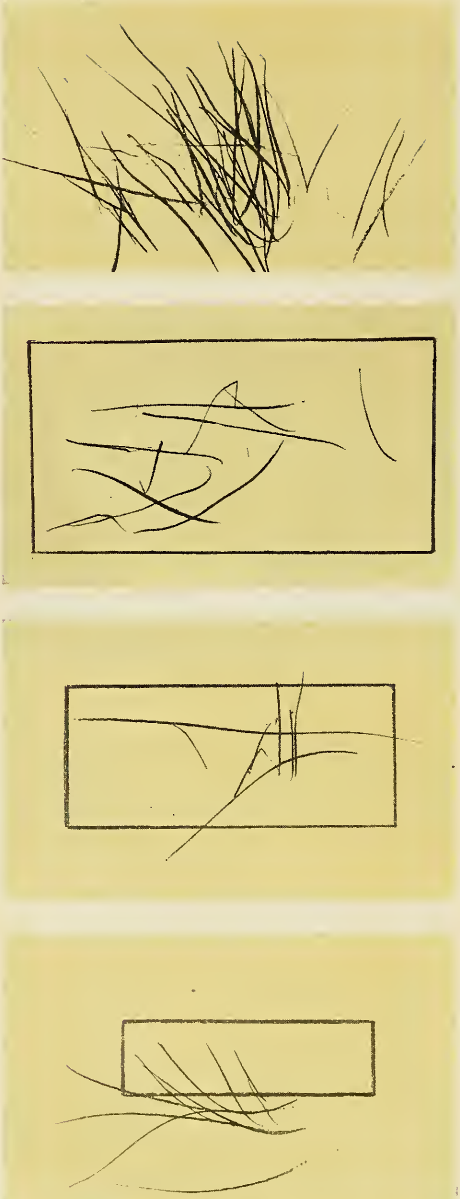
Clearly then, any new and essentially more simple form picture-making is of great experimental value. Infra- man paintings and drawings satisfy this requirement. e elements of visual organization that they contain are so ple that they can be analyzed in a way that is not sible with man's more complex, image-laden pictures.

AT the present time, pictures have been obtained from thirty-two apes and monkeys. Four species have been lved, the capuchin monkey—in Germany, Russia, and e United States; the orangutan—in England and Ger ny; the gorilla—in Holland and Switzerland; and the impanzee—in England, Holland, Germany, Russia, tzerland and the United States. The chimpanzee has so r proved to be the best subject: this species accounts for enty-three of the thirty-two animals studied to date.

The majority of the earlier primate investigations were



Calligraphy, *above,* is most advanced obtained from any ape at that time. Congo drew figure in third year of study.



Basic fan pattern, *top*, covered whole sheet when Congo was given blank paper. Given page with large rectangle on it, Congo altered pattern and drew within rectangle. Still smaller rectangle evoked a similar design, but some lines strayed over edges. The smallest rectangle was marked with lines starting outside it, was treated as object, not area.

Dr. Morris, whose report on experiments with Congo was adapted from *The New Scientist*, is Curator of Mammals at the Zoological Society of London. His book, *The Biology of Art*, will be published in London by Methuen & Co., Ltd.

brief and unsystematic but one or two involved a serious analysis of the results obtained. These were so promising that a young male chimpanzee called Congo was embarked upon a three-year experiment at the London Zoo, to provide an opportunity to study in detail the graphic potentialities of an infrahuman brain. This particular chimpanzee had proved himself to be of exceptionally high intelligence and possessed of a particularly alert and inquisitive disposition. Earlier tests with other chimpanzees had indicated that certain crude aesthetic rules could be brought into operation by this species and the goal of the study with Congo was to find out if any aesthetic principles could be formulated that would be sufficiently basic to be applied both to man-made and ape-made pictures.

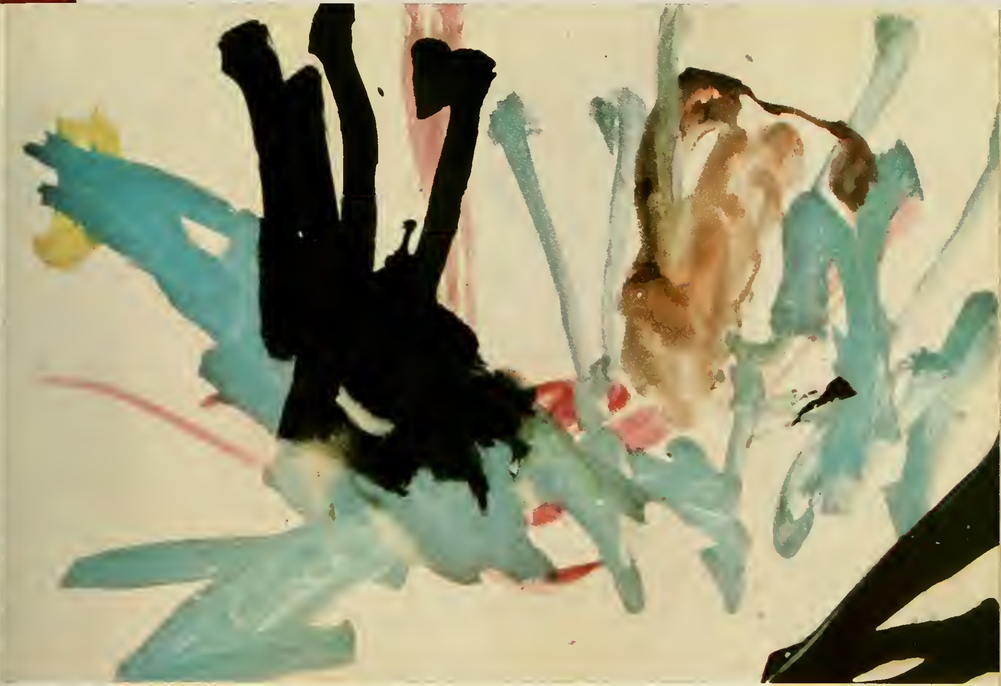
Congo first started scribbling when he was approximately one and a half years old. One day he was given a pencil and placed before a piece of card. The first contact made between pencil point and card was, of course, purely accidental, but, as Congo moved his arm and a line appeared on the card, he stared at it, moving his hand more and more. He repeated the movement and made line after line until the card was covered with a network of scrawls.

Congo produced many more drawings during following weeks and it soon became clear that there was a basic pattern that was appearing over and over again. It took the form of a fan-shaped series of lines radiating from a part of the card near the animal. It was also becoming obvious that Congo was reacting to the boundaries of the card or sheet of paper given to him. A large sheet resulted in a large drawing—a small sheet in a small one. Further, his work seemed to reveal a rudimentary sense of balance.

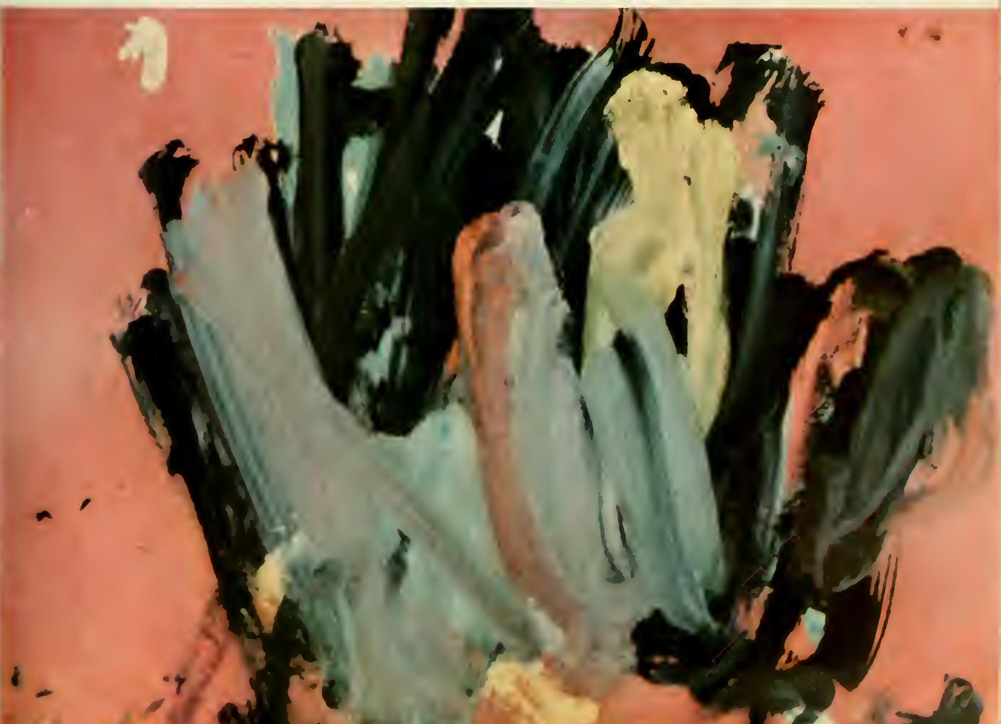
When Congo graduated from drawing to painting, his interest became even more intense. There were occasions when attempts to end a painting session resulted in screaming and temper tantrums. This, it should be emphasized, occurred despite the fact that Congo was never rewarded by the experimenter for drawing or painting. Picture-making seemed to be completely self-rewarding.

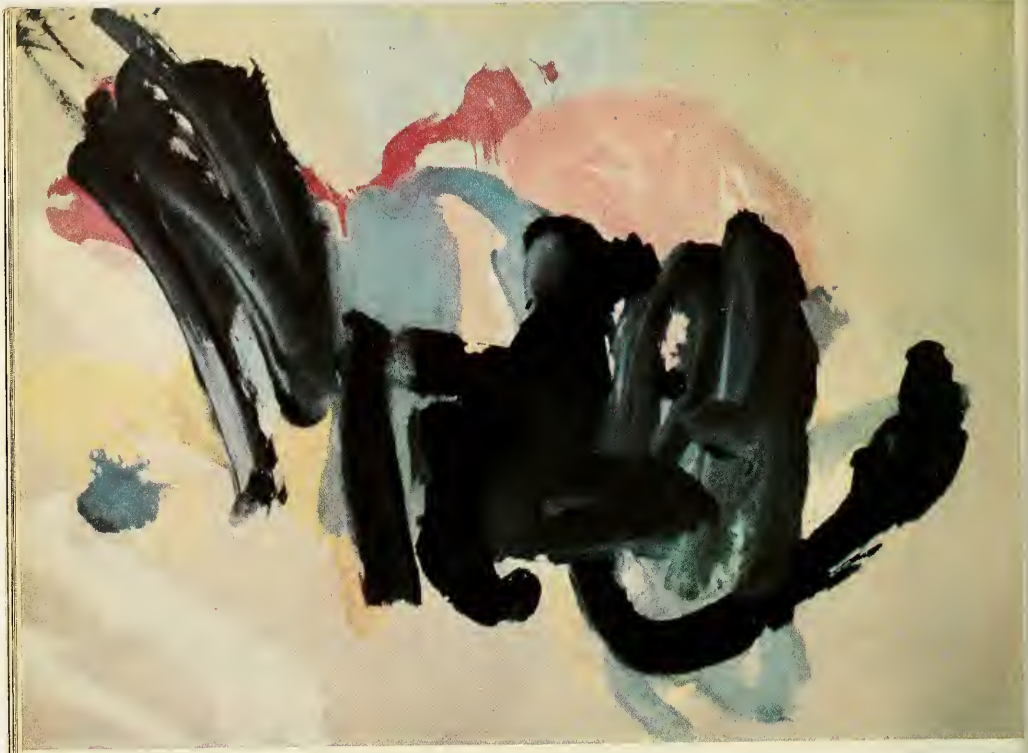
A painting session took the following form. Congo wa placed in a modified version of a child's high chair, with a sheet of paper laid flat in front of him. Pots of paint each with its own brush, were ready for him, but out o reach. A brush selected at random was handed to him. H painted until the paint was used up and then either put th brush down or handed it back to the experimenter. Th next loaded brush was given to him, and so on, each brush in turn being used in a random order until he was n longer interested in the picture. Then Congo would b given a new sheet of paper. Several paintings could b obtained thus in a session lasting about half an hour.

In early tests Congo had been given a free color choic but the method had soon been abandoned. On such o casions, he refused to start painting until he had mixed a the colors together into a uniform muddy-brown. This w avoided by presenting him with the colors one by one. H was still able to exercise a certain amount of color prefe ence, since he was at liberty to use each brushful of col

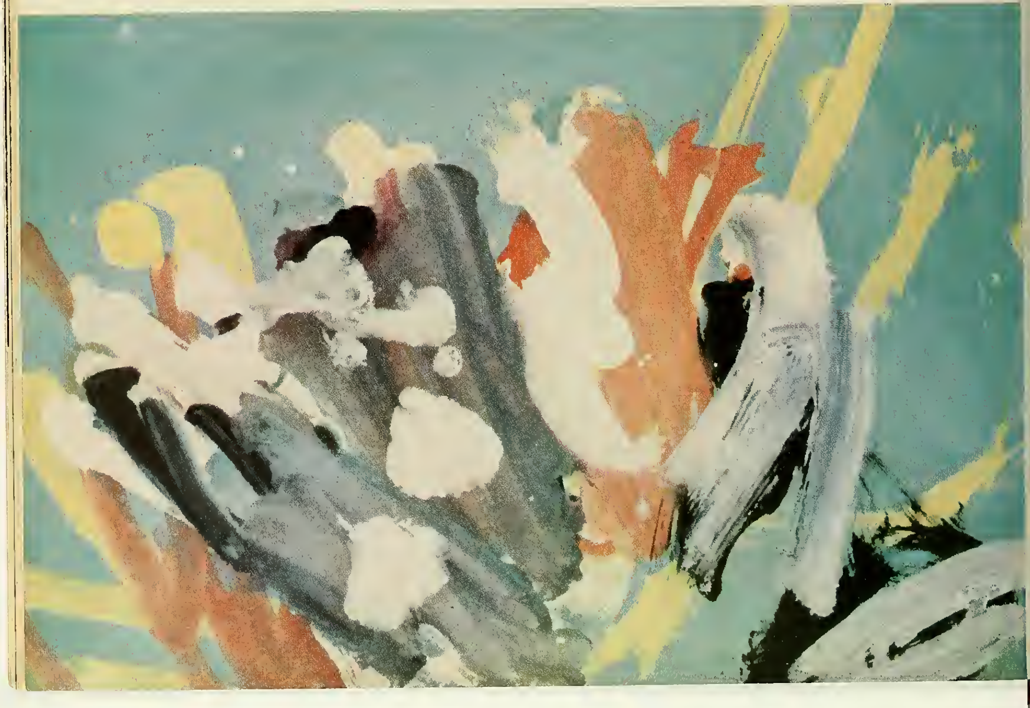


VARIATIONS ON A THEME are demonstrated in paintings by Congo, more than ninety of whose pictures contained basic fan patterns. Open, loosely knit fan motif is evident in top picture, while bottom effort has closed, crowded look.





CONVOLUTED DARK STROKES that seem to overpower lighter shades in painting above, lending it "violent" appearance, contrast sharply with paler coloring and relatively clean, simple brush strokes in the chimpanzee's work shown below.



s much or as little as he wished. Congo's main color prefer-nce was not so much for any one particular color. but ather for any color that he had not just been using. This ascination for variety of color was. of course. well served y the method used. and presenting the chimpanzee with a ifferent color with each brushful had the effect of re-eatedly boosting his interest in a particular painting. The utcome of this procedure was a series of rather com-licated pictures. a number of which were startlingly pleas-ıg to the human eye simply as abstract designs.

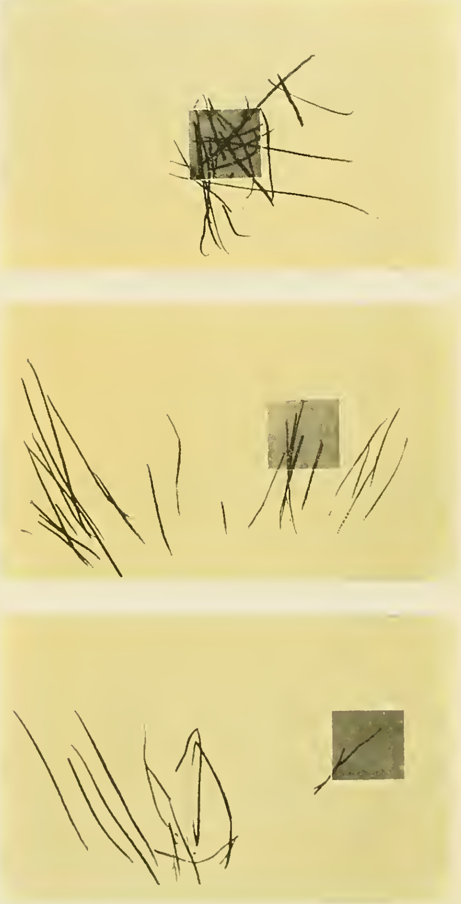
As in the case of the earlier drawings. the paintings were always scaled in proportion to the size of the aper on which they were painted. Also. the basic fan-haped pattern was often still utilized. Congo was becom-ıg much bolder now and frequently worked without hesi-ation. quickly covering the paper with determined strokes.

Perhaps his most remarkable painting is one shown on age 23 (*top*). Rays of a basic fan pattern are just dis-ernible. but. in addition. there is a quite distinct and well-ormed subsidiary fan motif in the lower right-hand corner f the picture. Previously it had always been argued that e fan pattern was the result of a simple motoric rhythm ı which the animal repeatedly pulled the brush toward imself from a series of different starting points. thus in-itably giving rise to a pattern that gave the impression f being visually controlled. As long as the fan pattern as always focused on Congo. it was impossible to decide hether the design was the secondary result of a kind of ild gymnastic repetition. or whether it was an indication at a chimpanzee was capable of a visually disciplined ttern formation. The fact that the subsidiary fan motif en here has its own quite distinct focal point strongly ıpports the view that the chimpanzee was doing something ther more than a simple muscular exercise.

In order to test the extent to which the form of Congo's intings were under visual control. a special series of perimental sheets was prepared. The fundamental ques-on was this: Is the position of a line that is about to be awn in any way determined by what is already present ı the paper? If the initial markings on the paper are t made by the chimpanzee. but rather by the experi-enter. then any influence that the markings may have er subsequent markings by the animal must be visual.

MORE than two hundred experimental drawings have been obtained from Congo and they are still being alyzed, although they reveal already that visual control in fact operating to a remarkable degree. Painting was andoned for this purpose. in order to simplify the linear alities for accurate measurements. A black crayon was esented to Congo. who was allowed to draw with it until lost interest. and then another sheet was put before him. lored crayons were not used to boost his interest in a awing. as this would have rendered analysis of the line sitions too complex. The simple scribbles Congo made ring these tests have already revealed several basic rules chimpanzee "composition." Some of these rules are ustrated by the drawings on pages 24. 27. and 28.

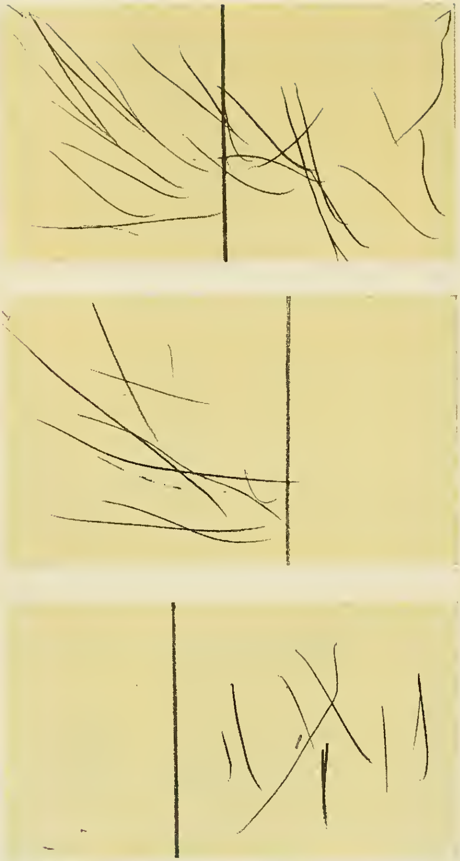
A simple fan pattern as drawn by Congo on a blank sheet paper is illustrated on page 24 (*top*). When a two-inch ay square was placed in the center of the paper before was handed to him. a design similar to the one shown



Two-inch square, **centrally placed on paper**, ***top***, **is the object of all Congo's markings. Slightly offset to right, square is still marked, but is partly balanced by lines at left. With square at far right, lines at left balance it.**

above (*top*) resulted. In this test and in all others where Congo was offered a centrally placed figure, he responded by confining almost all his lines to the region of the figure. This tendency to mark over well-defined figures came into conflict with another tendency, however. if the square was placed off-center. There was still an urge to mark it, but the more the square was positioned to one side or other of the paper, the more Congo tended to counterbalance it with his markings, rather than merely to mark it (third example *above*). In practically every one of the many off-centered test papers placed before him, Congo made bold markings on the side of the paper opposite the figure.

These early results reveal that in the chimpanzee there is what we might call the germ of visual composition, and



Central vertical line, *top,* **is normally ignored in the ape's drawings. If line is moved to right or left, however, Congo marks only larger, opposite part of paper. Drawings of the chimpanzee show nascent sense of visual composition.**

a whole host of new questions immediately springs to mind. They are being investigated, but even now it is nevertheless quite clear that the basic visual rules that control composition and design in painting by human beings are shown in a rudimentary form in the work done by Congo.

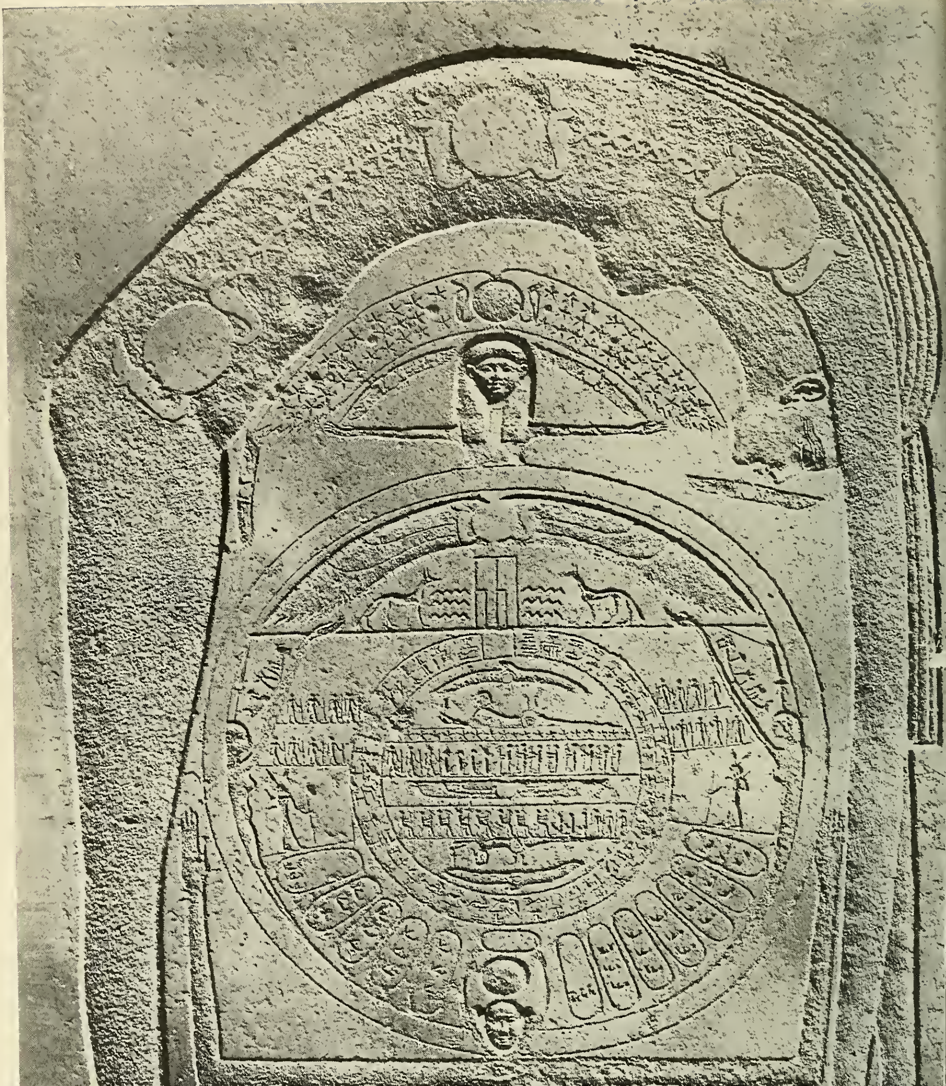
So far, the position of Congo's lines on the paper has been discussed, rather than the lines themselves. It is interesting that although Congo's sense of visual balance has been present in the same form almost from the start, his "calligraphy" has been changing gradually from month to month. In all the early pictures the lines were short, simple, and disconnected. Even the longer lines, which soon appeared as the rays of the fan patterns, were, when taken individually, comparatively simple. But, as he grew older, Congo began to experiment with longer, more meandering lines. Soon he was experimenting with loops and spirals and, after a while, complex multiple-horizontal scribbles appeared. At his present age of roughly three and a half years he has just arrived at the circle as a new motif. Naturally, with these more complex lines, the earlier fan pattern is rapidly vanishing from his picture-making, although he will sometimes combine the fan configuration with horizontal scribbling to produce complex patterning.

These calligraphic changes are particularly interesting when compared with those that take place in the very early scribbles of human infants. In almost all respects they ap-

ear to be identical. Human infants of similar ages pass rough the same stages from simple, short, disconnected nes to longer, simple lines, to meandering lines, to loop- gs and spiralings, to multiple scribbling and eventually simple "diagrams" such as circles, crosses, and squares. his process of simplification from the confusion of ultiple scribblings to the formation of distinct and simple agrams is of vital importance in the development of man picture-making, for it is from the combining of ementary diagrams that the earliest crude pictorial images are formed that, by a rather lengthy process of differentiation, eventually lead to accurately representational imagery.

It is remarkable that such decidedly similar early stages of calligraphic development are to be found in a different species, and one cannot help wondering at this point in the experimental process just how far any chimpanzee will ever be able to grope along this path of pictorial differentiation. Only after many more chimpanzees have been induced to abandon the branch for the paintbrush will we have finally found the answer to this really fascinating question.

ARLY EFFORT is eyed by Congo, who began to dabble in the ts at London Zoo at age of one and one-half years. His three years' yield of hundreds of drawings and paintings may give clues to origins of image-making by human beings.



SKY REPORTER

he Egyptian and Sumerian beginnings of cosmological theory

By Simone Daro Gossner

THE FUNDAMENTAL PURPOSE of astronomy is to under- stand the structure of the world around us. Our whole ncept of the universe and of the laws that govern it—in ier words, our cosmology—must be derived from the served behavior of the sun, the moon, a handful of inets, and myriad luminous specks in the night sky.

Even in the early stages of civilization, men could not l to note the daily rising and setting of the sun and rs, and the phases of the moon. The succession of seasons s associated in their minds with the periodic return of tain stars in the evening sky. Awed by the inexorable urse of celestial bodies, they invested them with super- tural powers. It is not surprising, therefore, that the -mologies of ancient peoples were invariably linked with ir religions and mythologies.

In later centuries, after astronomy had evolved into a ence, cosmological theories became concerned with the ional explanation of observed phenomena. With its oc- ional touches of prophetic insight, its frequent back- ling, and its alternating submission to—and rebellion inst—the pressures of prevailing philosophies, the prog- s of cosmology in the Western world from earliest times he present day is a remarkable illustration of the steady lution of scientific thought. Because of the particular rest of this subject, which cannot be dismissed in a paragraphs, we propose to depart somewhat from our tomary Sky Reporter format. From now until De- mber, we shall examine successively ten of the principal iods in the history of cosmological theories.

The most ancient civilizations seem to have developed ost simultaneously in Mesopotamia—between the phrates and the Tigris—in Egypt along the Nile, and at henjo-Daro on the Indus Delta. We know very little out Indus Valley culture, because its script is as yet deciphered. On the other hand, our century-old knowl- ge of Egyptian hieroglyphics and the painstaking trans- ion, in recent years, of Sumerian and Babylonian neiform tablets have revealed very plainly that the deni- s of these ancient cities had already acquired some as- nomical knowledge.

The earliest known Egyptian calendar, for example, is ed on a solar year, but the fact that its months have ty days indicates that it replaced a more ancient one ed on the phases of the moon. Little doubt remains that periods of these two astronomical bodies were known h some degree of accuracy by the middle of the fifth lennium B.C. However, the earliest written documents t archeologists have discovered so far date only from ut 3000 B.C. Thus, for practical purposes, the dawn of onomy belongs to the preliterate era in the history *Homo sapiens*; one can only speculate on the thought cesses that fashioned his first ideas on the universe.

The dominant factors in the life of ancient Egypt were annual rising of the Nile, which renewed the fertility of the land, and the daily course of the sun, which dispelled the dreaded night. A man's world was the flat piece of land on which he dwelt, limited by a circular horizon and surmounted by a domed sky; he traveled to other cities by boat along the river; above all, he lived a well-ordered life. Much of this is mirrored in his interpretation of the physical universe and of natural phenomena.

The sun was seen as sailing through the day on a celestial Nile. Since it reappeared in the east every morning, there had to be another river or sea in the underworld by which it completed its course. The earth was a disk held afloat on these waters by the earth-god Geb. Nut, goddess of heaven, stood arched over the earth (see picture at left), her body studded with stars. The obvious discomfort of her pose was eased by the proffered support of the air-god Shu. Oddly enough, this myth does not account for the diurnal and annual motions of the stars. Yet these motions must have been known from earliest times, because the abode of the dead was thought at first to lie in that part of the sky, near the celestial pole, where constellations never dip below the horizon (at a later period, the underground sea played a similar role).

Another, perhaps older, myth describes the sky as a cow with stars attached to her body, and some texts speak of the four pillars of heaven, which were believed to support the celestial sphere. The story of Nut, however, seems to have endured in Egyptian mythology for several thousand years, at least until the beginning of the Hellenistic period in the fourth century B.C.

WE know very little about the Sumerians, who preceded the Babylonians in Mesopotamia. The decipherment of their clay tablets is a slow and laborious task, but the available texts unfold a rich and imaginative mythology, much of which reappears in slightly disguised form in Babylonian and Greek fables.

There is no text devoted exclusively to Sumerian cosmology, but numerous references scattered among their legends make it possible to reconstruct these most ancient beliefs. In this rugged country, submitted periodically to the heavy floods in the Euphrates Valley and to the pummeling of severe windstorms, water and atmosphere appear as the most important elements of the universe.

The earth was viewed as a flat disk encased above and below in a solid sphere—presumably made of tin—and completely surrounded by water. The air-god Enlil separated the sky (his father An) from the earth (his mother Ki). The sun, moon, and planets were deemed luminous emanations of the atmosphere. As in Egypt, several thousand years must pass before a semblance of rationalization becomes apparent. Even the later and more sophisticated Babylonians, contrary to popular belief, seem to have based their astronomical calculations on empirical rules rather than any accumulation of theoretical considerations.

THE SKY IN JANUARY

From the Almanac:

Full Moon	January 1,	6:06 P.M., EST
Last Quarter	January 9,	10:03 P.M., EST
New Moon	January 16,	4:30 P.M., EST
First Quarter	January 23,	11:14 A.M., EST
Full Moon	January 31,	1:47 P.M., EST

On January 2, the earth will be at its shortest distance from the sun (perihelion) for the current year.

For the visual observer:

Mercury will be in superior conjunction with the sun on January 5, entering the evening sky on that date. Thus it will be too close to the sun for observation during most of the month. At month's end, it will set about an hour and fifteen minutes after sunset but, even then, it will be very low in the sky, to the west–southwest.

Venus, in the evening sky, will brighten from —3.8 magnitude on January 1 to —4.1 the night of January 31. Its greatest eastern elongation is on January 28. Very brilliant in the west, it will set three and a half hours after sunset on January 1, four hours after on January 31.

Mars, in Gemini, will be visible most of the night this month. Its distance from the earth will increase from 57 million miles on January 1 to 69 million on January 31, with a corresponding decrease in brightness from —1.3 magnitude to —0.5 magnitude. It will pass nearly overhead at about midnight, local time, on January 1, at 10:30 P.M. on January 15, and at 9:30 P.M. on January 31. It will set shortly before sunrise in early January, one hour before at midmonth, and about 5:00 A.M. on January 31.

Jupiter, in Sagittarius (—1.4 magnitude) will be in conjunction with the sun on January 5 and will be lost in its glare during most of the month. By January 31, it will rise one hour before the sun but may be still difficult to see in the morning twilight.

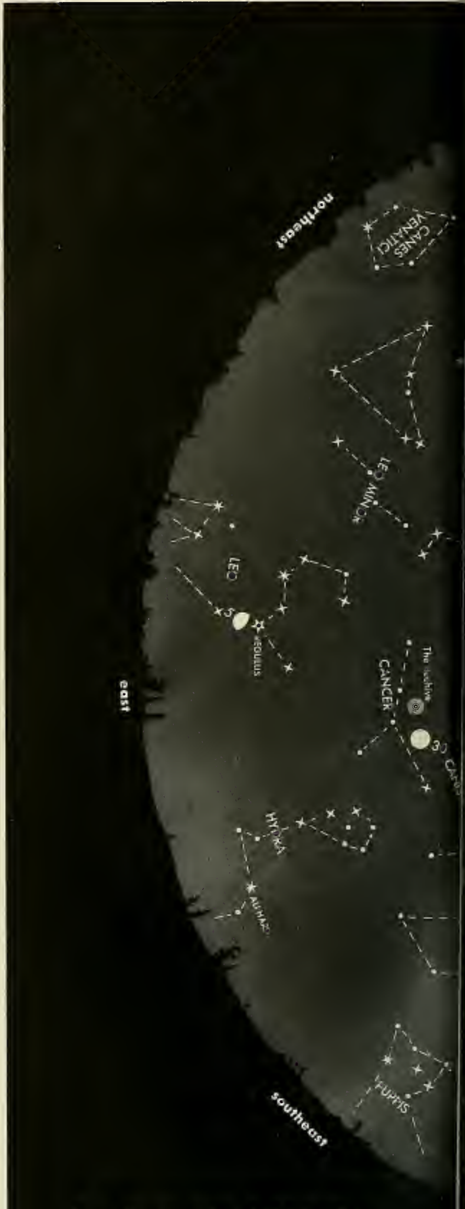
Saturn (+0.8 magnitude) will be in conjunction with the sun on January 11. Only a few degrees will separate it from Jupiter, and it will be equally unfavorable for observation by reason of its proximity to the sun.

The Quadrantid meteor shower will occur on January 3. Unfortunately, the moon will be two days past full on that date and will be bright enough to obliterate the fainter meteors. This shower tends to reach its peak abruptly, and the number of trails visible to a single observer may vary appreciably from their predicted rate of 40 per hour.

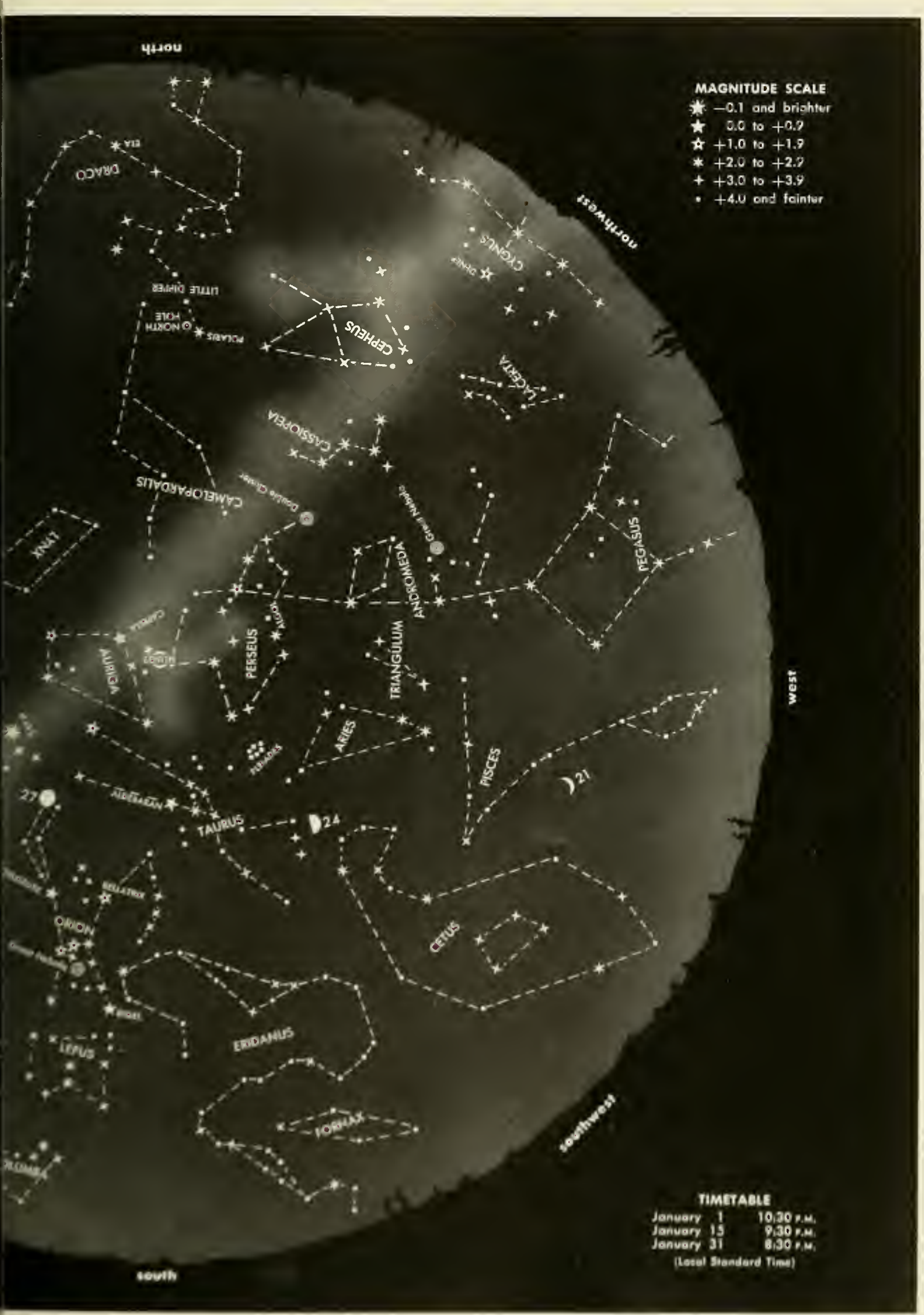
An unusual star group:

The brightest star in the constellation of Gemini (see map) is most remarkable. It consists, in fact, of six stars in such close association that their combined brightness makes them appear as the single object we call Castor. Two of the six components form a binary system revolving around each other in a period of nine days. Two others form another binary system with a three-day period. The two binaries themselves revolve around each other in about 350 years. Finally, the remaining two stars in Castor form a third binary (with a period less than a day), which slowly revolves around the quadruple system described above, in a period estimated at a few thousand years.

This year, MRS. GOSSNER presents a series on the growth of cosmological concepts. This is the first of the series.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.


north
northwest
west
southwest
south
DRACO
ETA
LITTLE DIPPER
NORTH POLE
POLARIS
CEPHEUS
CYGNUS
DENEB
LACERTA
CASSIOPEIA
CAMELOPARDALIS
Double Cluster
LYNX
Great Nebula
ANDROMEDA
PEGASUS
PERSEUS
ALGOL
CAPELLA
AURIGA
TRIANGULUM
ARIES
PLEIADES
PISCES
21
24
27
ALDEBARAN
TAURUS
BETELGEUSE
BELLATRIX
ORION
Great Nebula
RIGEL
LEPUS
ERIDANUS
FORNAX
CETUS
COLUMBA

MAGNITUDE SCALE

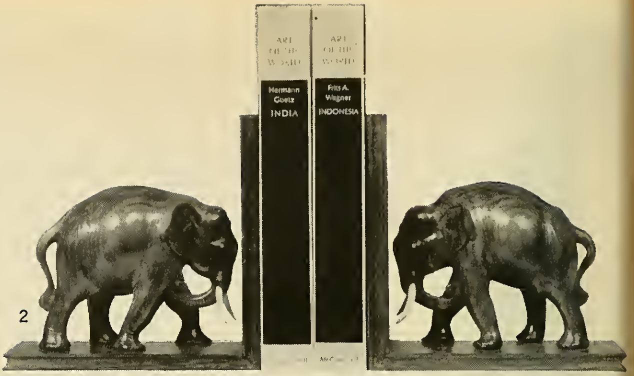
- ✸ −0.1 and brighter
- ★ 0.0 to +0.9
- ☆ +1.0 to +1.9
- ✱ +2.0 to +2.9
- + +3.0 to +3.9
- • +4.0 and fainter

TIMETABLE

January 1	10:30 P.M.
January 15	9:30 P.M.
January 31	8:30 P.M.

(Local Standard Time)

1

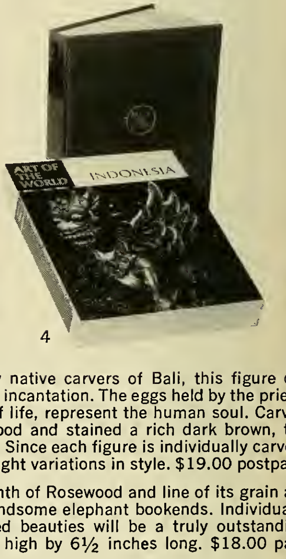


2

THE ART OF THE EAST

TO ENHANCE YOUR HOME

ART OF THE WORLD
INDIA
3



4

1. **Balinese Priest**—Handcarved by native carvers of Bali, this figure depicts a Balinese priest delivering an incantation. The eggs held by the priest, fragile and imbued with the seed of life, represent the human soul. Carved from a solid block of Bentawas wood and stained a rich dark brown, the figure stands about 13 inches high. Since each figure is individually carved, no two are exactly alike and have slight variations in style. $19.00 postpaid.

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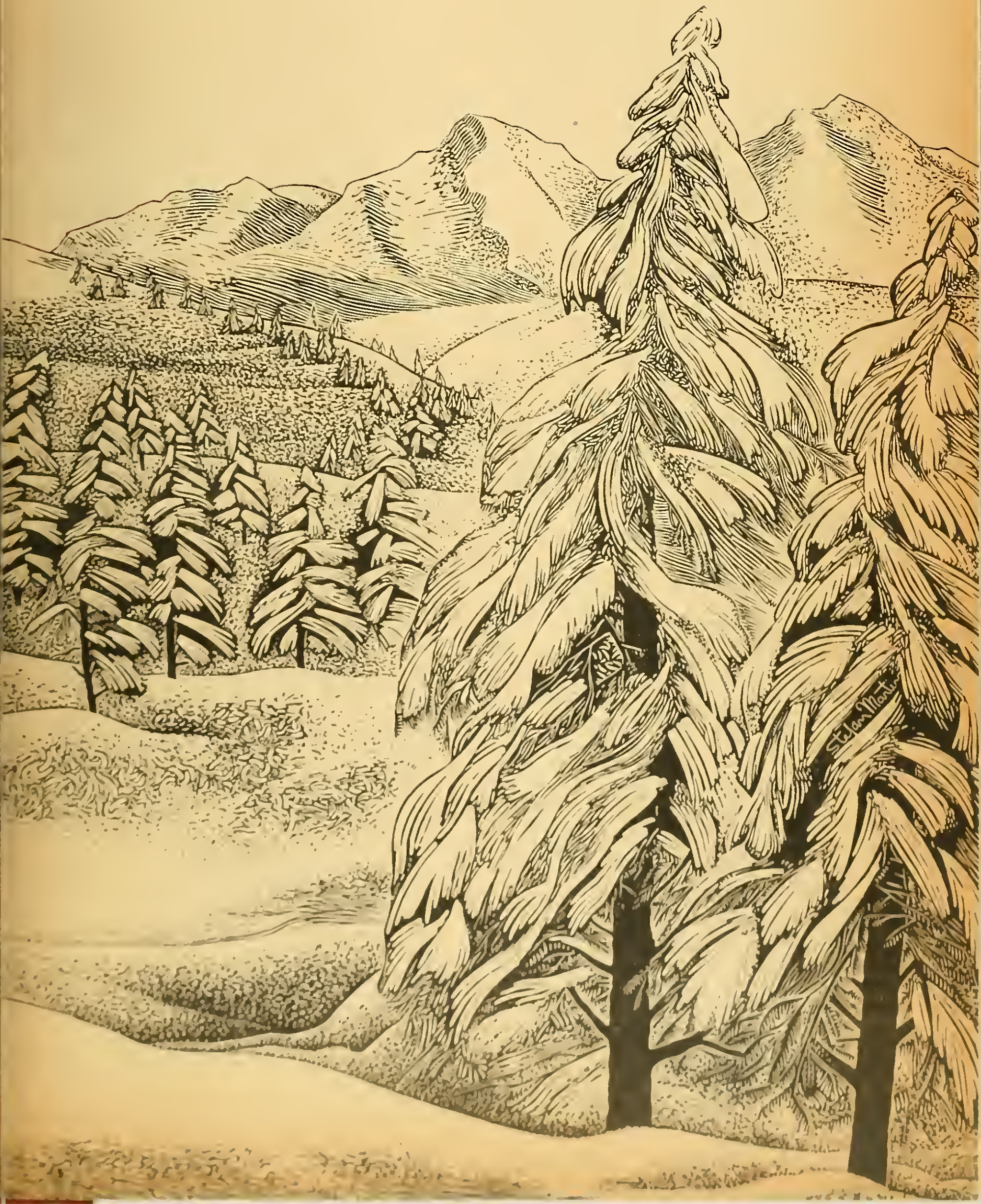
Stefan Martin

Weather changes as the *form* of water in the air alters the amount of water vapor present. Extremely cold air is much drier than that ranging from 24° to 30° Fahrenheit, between which two temperatures the heaviest snowfalls take place.

THE SNOW BLANKET

Management methods can make snowfall an asset or a liability

By E. Laurence Palmer

The inhabitants of the continental United States—with the exception of those living along its extreme southern border—are accustomed to annual, or at least occasional, snow blankets. In some places, the snow blanket may be permanent. In other places it may last only a few hours or days. In thickness, the yearly accumulation may vary from less than one inch to more than eight hundred inches.

The snow blanket may remain in a fixed position, may move almost imperceptibly, or, as an avalanche, may move unpredictably and at great speed. It may possess characteristics that can, within certain limits, be profitably utilized by humans. It also has its disadvantages, which to some extent can be nullified.

A snow blanket is both an asset and a liability, a joy and a threat, and a thing of beauty. Unmanaged, it may also represent a prodigious waste of a precious resource. In spite of the fact that its existence is almost universally known, its role in the scheme of human life is generally little understood. Although the snow blanket may take a life or save one, its management has received only slight attention.

Playwrights, artists, musicians, poets, engineers, and outdoor people all make their own special interpretations of the role that snow blankets play in their own lives; but for the most part its existence is ignored by the general public, whenever possible. Snow blankets offer a challenge to industry, agriculture, commerce, and practically every other phase of human activity; but they rarely, if ever, are subjects for study in our schools. They deserve to be better understood.

The history of a plant or animal follows a definite sequence, from birth to death. It is a sequence that cannot be reversed, even temporarily. But the history of a natural phenomenon, such as a snow blanket, can be a sequence, or series of sequences, whose order may, and often is, repeatedly reversed.

Basic to the creation of a snow blanket is the water vapor of the air. The abundance of the vapor varies with temperature, wind direction, and other factors. Warm air is capable of holding more water vapor than cold air; and, as the warm air cools, it loses its vapor in the form of fog, rain, or snow.

The physical form of the precipitation is largely determined by temperature. Above the freezing point,

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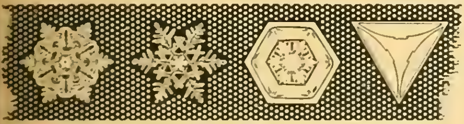
Dr. E. Laurence Palmer, for many years director of Nature Magazine's educational program, continues his special inserts in the pages of the combined magazines.

water in the air returns as rain, which is not ordinarily part of a snow blanket. Below the freezing point, precipitation may occur as snow. Large, lacy flakes are formed at relatively low altitudes and high temperatures. Under conditions of high altitudes and low temperatures, water vapor may be precipitated to earth in the form of fine discs and plates of ice.

THE discs and plates are ordinarily three- or six-sided planes. If the bits of solid ice fall through drier air, they may, by sublimation, be re-absorbed without assuming a liquid form. Even after the flakes reach the ground and accumulate in snowbanks, they may return to the air as water vapor through sublimation, without adding to the water of the earth's surface.

As a blanket, snow may permit the passage of light and allow for changes in temperature, as well as some movement within itself; but, in general, snow blankets act to retard changes and to temper extremes. Such changes can be controlled in greater or lesser degree by human management of snow.

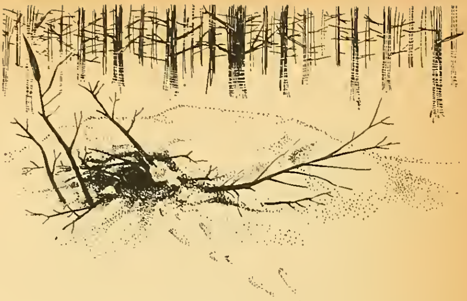
Food production is, of course, an important element in the sum total of the nation's economy. For a number of years past, in the United States, more and more food has been produced by fewer farmers, on less acreage. This state of affairs is largely attributable to the utilization of machines, in combination with a more intelligent management of the land. Such management has taken the snow blanket into account and has related it to sustained water supply, reduced soil erosion, and the mitigation of weather damage.


Low altitudes and warm air make complex snowflakes, while simpler types come from high altitudes where air is colder.

We cannot produce snow at command. We can, however, by the wise use of barriers, anchor the snow blanket, to the end that the frost line in the ground may be kept nearer the surface, so that water may penetrate the soil to build up underground water reserves on which we can draw in the future.

Shelter belts, terraces, strip-cropping, and good wildlife management practices prevent many crises associated with soil freezing, too-rapid melting of the snow blanket, and wind and animal damage. Where snowfall is light, the ground may freeze to a depth of more than six feet during early winter. A snow blanket of a foot or more depth during the bitter weather of January and February may prevent the soil beneath it from freezing to a depth of more than a few inches.

THE snow blanket may also keep the temperature, at the point where soil and snow meet, as much as fifty degrees higher than that of the open air. Even relatively small domestic animals, like sheep, may survive extremely low temperatures under the protection of snow. Crops like winter wheat, protected under the snow blanket, survive where they would otherwise be destroyed. Facts like these accentuate the real worth of the snow blanket to the agriculturist.

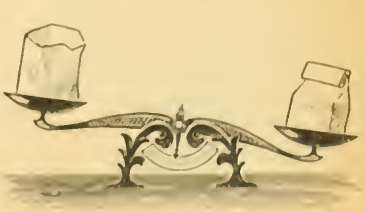

Snow-covered brush pile offers haven to small animals that are hard-pressed to find shelter in leafless winter woods.

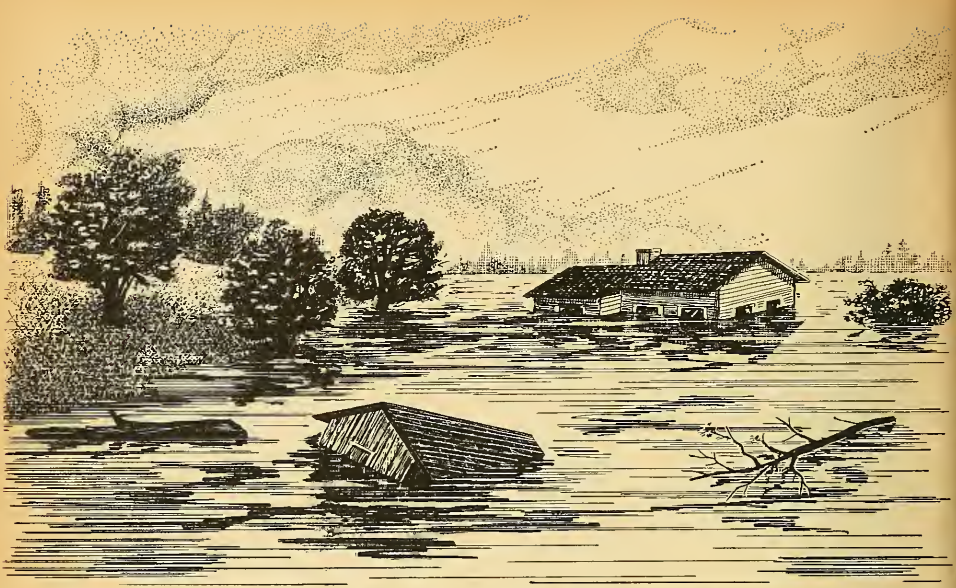
To the city dweller, a snow blanket is usually nothing more than a nuisance, or a seasonal novelty. In reality, however, it is a phenomenon of major importance to city and countryman alike, and is likely to have a far-reaching effect on both.

If an unduly heavy snow blanket has an adverse effect on agriculture, this will be reflected in prices and farm profits. With the coming of snow, human transportation problems increase, and the problem of snow removal may seriously deplete the financial reserves of a town or a state. Snow and slush may affect human health, and consequently the earning power of those engaged in making, marketing, and using the items that go into the national product. Winter conditions, on the other hand, create a demand for special clothing, which in turn is reflected in additional consumption of raw materials and an increased demand for labor in many different industries—from shoemakers to hat manufacturers.

THE snow blanket also produces seasonal situations that affect the yearly earnings of people engaged in outdoor labor. New home construction, for example, may be suspended during the time that a heavy snow blanket covers the ground. The weight of the snow blanket on buildings may even affect the nature of local architecture.

Snow conditions have an effect on home problems such as heating budgets and the need for special snow-removal equipment. Many winter casualties are directly traceable to unaccustomed physical exertion on the part

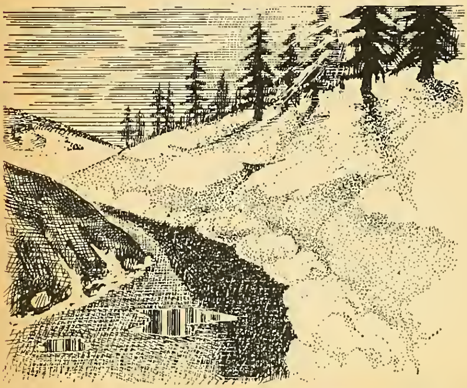

When ice changes directly into vapor without melting, snow does not form and add to weight of blanket on the ground.



Sudden melting of a deep snow blanket during unseasonably warm weather or after heavy spring rains can produce floods that destroy livestock, crops, and human lives. The economic effects are incalculable in soil erosion and loss of water.

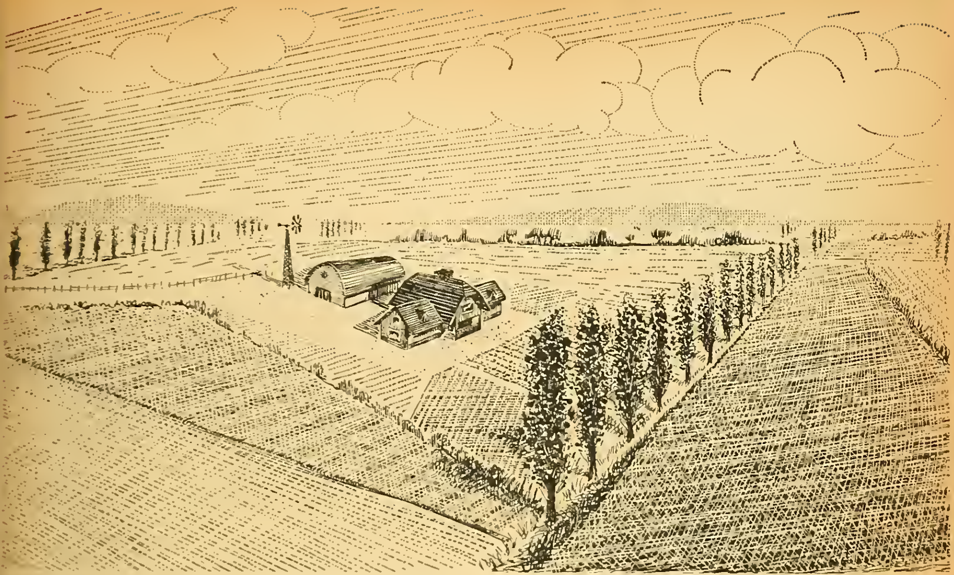
of persons faced with the chore of keeping driveways and walks passable. Snow, then, has both a direct and an indirect role to play in the economics, the health, and the living conditions of the nation's inhabitants, and its industrial and commercial life.

Stories carried by press, radio, and neighborhood chatter tell of the troubles that may be caused by a snow blanket. Slippery surfaces bring an increase in the accident rate. Some snow-caused accidents are fatal; others are crippling; still others are painful, inconvenient, or embarrassing. An increase in vehicular accidents, both expensive and disturbing, arrives with the snow blanket. The snow may perhaps defeat the purpose of a special department store sale, with its expensive preliminary preparation. Theatrical, political, and sporting events may fail because of an abnormal snowfall. School activities may be suspended during and after heavy snow storms, and lost school work must be made up, if possible. It is even conceivable that political meetings could reach unforeseen conclusions, and new faces appear on the



Light aids in the management of the snow blanket, and roads absorbing or reflecting light help regulate snow clearance.

Depth of the snow blanket has great effect on an animal's ability to move, find food, keep warm, and avoid predators.

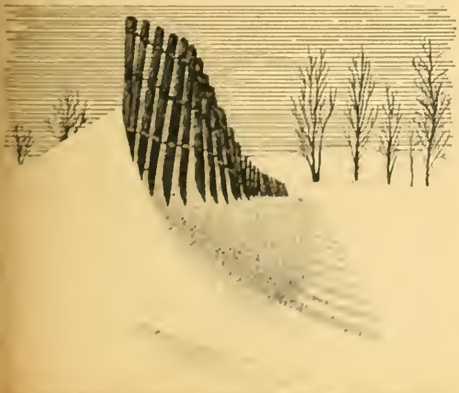


Windbreaks, such as trees planted between fields, may cut damage caused to farm land by wind damage and heat loss. A planting also helps to control the amount and the speed of spring runoffs, and to prevent any serious soil erosion.

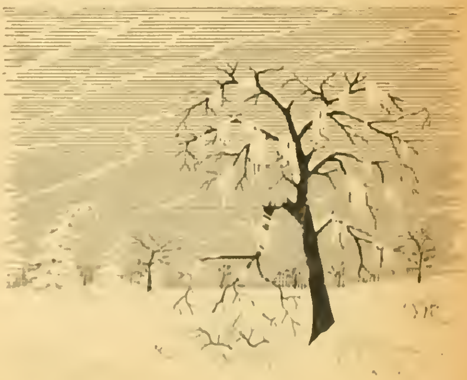
political scene, because of the limiting effect of a heavy snowfall on some of their participants.

Snow blankets are capable of wrecking orchards and shade trees, and of disrupting communication systems. They may sometimes lead to human death by starvation or by freezing. The sudden disappearance of a deep snow blanket during unseasonably warm weather or because of heavy spring rains may produce floods destructive to cattle, crops, and humans. Even the *absence* of a normal snow blanket may be a menace. Such a condition may well contribute to drought during the seasons that follow. It is fair to say, then, that the snow blanket, without management, may be considered a potential menace to many aspects of human welfare.

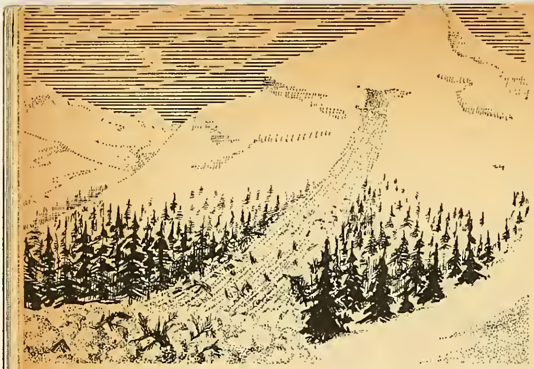
A snowbank is an agency of moderation. It functions as a bridge between extremes of heat and cold, drought and flood, starvation or survival. Fluctuations between such extremes may occur over short periods of time, in short units of space, and in small units of abundance. Each special situation may be a critical one, not only for



Transportation of snow by wind or water can be checked by the use of barriers such as trees or snow fences, as above

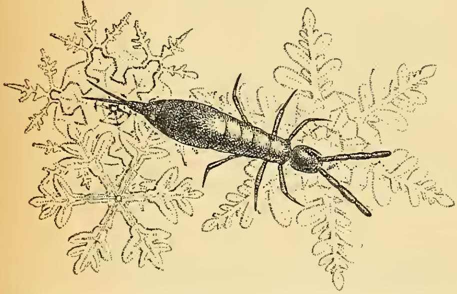


Weight of snow alone can destroy some trees and herbs, and ice glazing or snow mass may destroy certain animals, too.



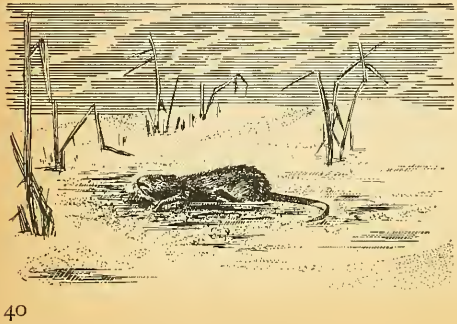
Avalanches may result from snow falling upon steep inclines.

Play opportunities are among the definite benefits of snow.



Tiny insects, *above*, live in snow and may be eaten by birds.

Muskrats, *below*, can become fatally trapped in slushy water.



plants and animals, but also for units of physical environment, like soil, streams, or even the topography of an area.

In the absence of an adequate water supply throughout the year, many plants and animals would necessarily perish. Snowbanks lessen the likelihood of drought following on the heels of flood by holding water in its frozen form and gradually releasing it. As a tempering factor, snow serves to maintain plant and animal living-spaces in a condition neither too hot nor too cold, allowing the occupants to survive temperatures that might otherwise prove fatal. The snow cover is a great reservoir of future water. The winter accumulation of great depths of snow in a mountain fastness will later feed a stream that may, perhaps, water thirsty lands hundreds of miles distant.

To wildlife, the snow blanket may mean the difference between life and death. For example, hunting seasons for "big game" are closely integrated with the coming of the snow season. If the blanket comes early, and game is easily tracked, the kill of large mammals may be unduly heavy, and populations correspondingly reduced. If the carpet is thick and soft, only the long-legged animals may move about freely. Such simple factors as the depth of the snow blanket and the length of an animal's legs often mean the difference between survival or death.

If the snow carpet is covered with a crust, the hardness of the crust, as well as the weight of a running creature, become survival factors. Predators like weasels can take advantage of the awkwardness of heavier animals like rabbits, just as a dog may take advantage of a larger and heavier deer in a life-or-death pursuit through deep snow.

The snow crust also may act as a death trap for birds like grouse, which often bury themselves in soft snowbanks; or to pheasants, whose long tails may freeze into the snow while the bird is at rest. The snow blanket may deny life to animals of all kinds by forbidding them access to ordinary food sources. Particularly interesting, from the human viewpoint are the trails left by wild animals in the snow. Such trails are rather easily identified and interpreted. The thirty-seventh number in this series, under title of "He That Runs May Be Read," described and illustrated the tracks and trails of more than a hundred wildlife representatives.

In the earlier days of the nation, human survival often depended on the ability of the inhabitants to understand the snow blanket and, if possible, to take advantage of it. Even today, crises in our modern transportation system, or perhaps the sudden outbreak of war, might at any time force us to cope with a snow blanket on a most serious —perhaps even a life or death—basis.

On the lighter side of the picture are the recreational opportunities offered by the snow carpet to children and adults alike. Children, of course, enjoy making snowballs, snow men, and snow "forts." In a more serious vein, it might be suggested that, in connection with the civilian shelter programs that are now being carried on in various areas, each community could, during the proper season, erect a few good snow shelters. Such shelters might well serve as temporary havens in times of sudden emergency.

Igloos, similar in many respects to those of the Eskimos, may be constructed of blocks of snow that have been hardpacked by trampling. The snow is cut into blocks about three feet long, one and a half feet wide, and a half-foot thick. The igloo, or snow house, is best built on a base of hard-packed snow at least three feet thick. (You will find the essential steps in the construction of an igloo illustrated on page 46.)

Thirteen blocks of the indicated size are placed on edge in a circle on the base. Beginning at the bottom of one of the blocks, and ending at the top of the preceding one, a spiral is marked on the circle of blocks, and the blocks are cut accordingly. As indicated in the sketch on page 46, the blocks are so placed as to form a dome, and an entrance cut to form a heat-trap below floor level. In such a snow house, if it has been carefully made, food may be stored, and two people may sleep in relative comfort and warmth.

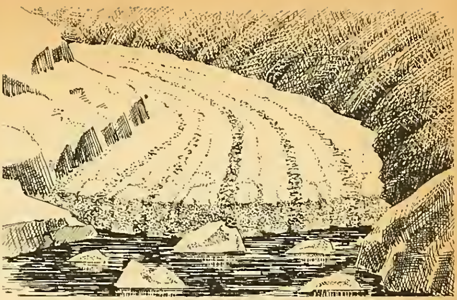
Interest in winter sports, which are dependent largely on the depth and quality of the snow blanket, has increased phenomenally in the past decade or so. Winter games of national and international flavor are becoming increasingly commonplace. The weekend exodus of hordes of city dwellers, equipped with skis and other sporting paraphernalia, is a familiar sight on our highways today, and rivals the summer migration to the country's many lakes and beaches, or camping sites.

SUCH winter sports are, of course, based on the slippery nature of accumulated snow. To most youngsters, the sled is a basic instrument. Their elders may pursue the art of bobsledding, with experienced and trained participants contributing to both records and safety. Tobogganing is, of course, a much slower and safer form of winter sport—unless the participants happen to strike a patch of ice at the bottom of the toboggan run. Snowshoeing is slower yet, but has its rewards for vigorous folk; it is an art still practiced by many trappers, miners, foresters and hunters, and is the occasional resort of rescue workers in times of blizzard.

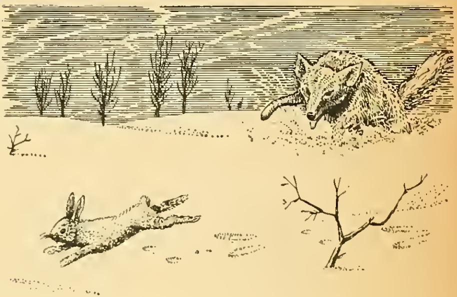
A natural phenomenon as universal as the snow blanket must find its place in the arts, as well as in science and economics. Homely words about snow have a place in our everyday conversation, and we are delighted by the word-pictures drawn for us on the subject of snow by the writers of prose and poetry. In the celebrated poem, *The Night Before Christmas*, we hear of the moon on the crest of the new-fallen snow, and how it gave "the luster of midday to objects below." A picture of some of the grimmer aspects of snow can be found in the Jack London story, "To Build a Fire."

Snow always seems whiter than a Monday's wash, even after the latter has been subjected to the most efficient and widely advertised detergent, and somehow the word "chaste" creeps into many descriptions of snowy scenes. One poet speaks of the "double triad of perfect snowflakes," with a degree of scientific accuracy. A more practical soul tells us that "The snow had begun in the gloaming," and continued on through the night to successfully alter the appearance of the land.

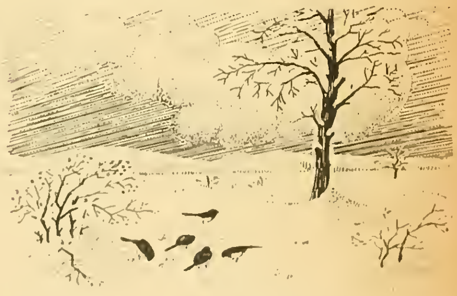
WRITERS of proverbs tell us that a "Snow year is a rich year," and that "a year of snow is a year of good." They also say that "snow which lies fattens the land," and that "crops under water presage famine, and under snow, bread." Farmers once referred to snow as "poor man's fertilizer." A particularly vivid feeling for snow may be found in the introductory paragraphs of the story "Krag the Kootenay Ram," in Ernest Thomas Seton's book, *Lives of the Hunted*.



Where snow is constant, ice may build up to form glaciers.

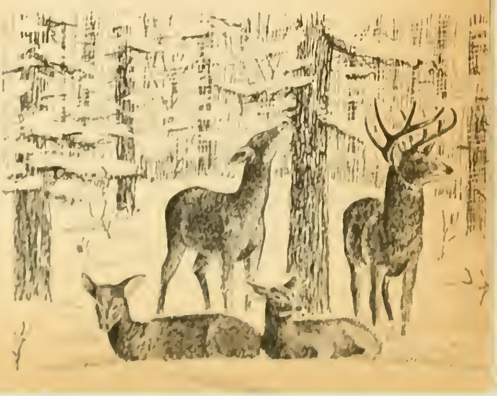


Snow crust can help small animals escape a larger predator.



Seeds held by surface snow help feed winter birds, *above*.

Deer herd, *below*, may pack snow down to form open shelter.



	DESCRIPTION	FACTORS INVOLVED
Water Vapor in Air	Air at various levels above the earth's surface varies greatly in temperature, weight, water vapor content, movement, barometric pressure, and other factors. Change in form of water in air produces rapid or slow changes in amount of water vapor in air, with corresponding changes in weather.	Air at 0° F., holds about ⅓ the moisture it holds at freezing, while air at −30° F. is about five times as dry as air at zero. Heaviest snowfalls occur when temperature ranges from 24° to 30° F. Changing of water vapor into snow may affect the air temperature of an area for some time.
Condensation	Snow crystals are usually 3- or 6-angled frozen planes of water sometimes paired, parallel, and connected. They may be rather even-margined disks, or elaborately but symmetrically fragmented along their margins. May be compacted, through violence, into tiny spherelike pellets.	Crystals formed at high altitudes and low temperatures are usually of the thin, regular, disk type; while those formed at low altitudes and relatively high temperatures are of the loose, feathery type. Either, or both, may be changed into pellet type by violent wind actions; may be intermixed.
Sedimentation and Stratification	Snow falls to the ground under varying conditions of temperature, violence, and humidity. In the United States, there are places having annual accumulations up to 800 inches. Others receive less than 1 inch. Fallen snow is subject to either slow or sudden changes over periods of a day or longer.	New-fallen snow may be mixed with greater or lesser amounts of air, and is variously affected by changes of air and temperature. Snow forms a useful thermal blanket that limits sudden changes; if a crust is formed, temperature differences in a vertical inch may easily exceed forty degrees.
Evaporation and Sublimation	Much of the accumulation of snow in any area may never contribute to raising the local water table, to filling depleted reservoirs, or to restoring other water reserves that may be needed in time of drought. Much may be lost by immediate evaporation, or by sublimation of snow into the air.	Air at an excessively low temperature is relatively dry. Sublimation of snow — the changing of solid ice into water vapor without melting — builds up water vapor in the atmosphere, reduces the hazards of floods due to later melting, and tempers the potentially dangerous changes of the spring season.
Melting	Melting of the snow cover brings an element of danger as well as many problems of water management. Warm rains may melt deep snows rapidly and swell streams. Although rapid melting may cause floods and destruction, such changes are all a part of nature's transition to the growing season.	Direct sunlight, the arrival of warm winds, and the lengthening of the day may accelerate melting—advantageously or otherwise—and means of controlling rapid melting should be understood. Forests or tall weed cover may provide enough shade to produce significant lag in melting.
Metamorphosis	As with most things in nature, change is the order of the day with snow and the snow blanket. Newly fallen snow is almost immediately subject to pressures from adjacent snow, to changing temperature, and often to abrasion by movements of adjacent objects. Changes or metamorphoses result.	Changing of water from a solid to a liquid, or a liquid to a gas—or the reversing of such processes — involves considerable heat transfer in one direction or the other; a snowbank, with its base on warm ground and its surface exposed to cold air, provides a setting for great variations.
Temperature Management	Management of any area presupposes an understanding of temperature variation, based on surveys, showing differences due to vertical or horizontal position, to compass direction, and to the nature of adjacent areas. It should also take into account the available means of insulation.	While ideal snow management is beyond man's control, planning can frequently reduce the hazards involved, within limits. Windbreaks may temper wind damage and heat loss, while color may contribute to heat absorption from the sun. Presence of a snow blanket definitely affects thermal strata.
Weight and Impact Problems	Weight of the snow cover may destroy some trees and other plants by weight alone. Ice-glazing may be even more destructive, not only to plants but also to the works of man. Because of the impact of dense masses of falling snow, certain types of plants and animals may be destroyed.	The weight of animals moving over snow affects their ability to escape capture, particularly as large animals cannot travel as lightly over snows and crusts as smaller animals. Snows compacted by the feet of animals into runways may possibly provide a record of the animal's search for food.
Light	Light and its associated heat does much to regulate the life and extent of a snow blanket, large or small. Normally, snow vanishes more quickly from areas exposed longer to the sun. This creates sharp contrasts in events that take place above or below ground in such localities.	Angle of the sun, and the color, size and nature of extraneous materials on the snow affect the melting rate of a snowbank, as well as the volume of consequent runoff. Light absorbed by, or reflected from, adjacent areas must be considered, along with light penetrability of snow blanket.

WILDLIFE ROLE	MANAGEMENT	ECONOMICS
Dryness of bitter cold air may affect survival of wildlife, its endurance, and consequently its behavior. When invisible water vapor in the air changes to visible fog, or vice versa, the ability of animals to move about, find food, and avoid enemies may be affected in various ways.	Fog blankets are frequently used to delay killing frosts in orchard areas, and smog, often associated with fog, may be used as a management tool. It may also be a health and safety hazard, particularly in cities, where smoke control is poor, and where water vapor may be highly concentrated.	Real estate values, crop values, recreational values, and health values of areas may all be profoundly affected by the water vapor content of associated areas. Expense of snow removal connected with water content of the air may mark the difference between economical or expensive existence.
Newly formed snow in air may limit vision of living things. Quick freezing produces small crystals that do not rupture cells of stored plant or animal matter and, by prolonging the usefulness of stored materials, reduces the demand for wastefully large harvests of fish, birds, and game animals.	Snow and ice crystal management is based largely on management of accumulation. Thus, variations in temperature, in amount of available air, and in pressures induced by weight may be stabilized and used to advantage by men and other living things. Man's influence is most active.	Snow in the air contributes greatly to winter accidents by limiting vision. Fragmentation caused by formation of ice crystals in growing crops, in stored supplies, in farmed soils, must be controlled to produce a sound economy, whether in an organism, a community, or a large territory.
A snowbank is rarely homogeneous from top to bottom, and its nature largely determines the ability of living things to survive and to move about under the snow cover. Variations in weather may be recorded in snowbank strata, in glaciers, and in other such frozen accumulations.	Snowbank management involves preservation or elimination of snow to meet the needs of organisms that normally move about on their surfaces; those that burrow between their upper and lower surfaces; and those that explore the base of a bank where food may be abundant and enemies rare.	Stratification of a snowbank is a continuation of the physical variations observable above and below the snow accumulation. Management of the snow stratum may be of economic importance to farmers who raise winter wheat; or to those whose orchards may be destroyed by mouse damage.
The orderly reduction of accumulations of snow by sublimation greatly reduces the dangers and problems of wildlife living where snowfall is substantial. So inconspicuous is the process, for the most part, that it is not recognized by many; it is, however, an important factor in the water cycle.	The loss of water through sublimation from exposed plant tissues may contribute considerably to winterkill, affecting the physiology of plants much as would a prolonged drought. This happens at a time when water losses cannot easily be restored, because water is held in the ground by freezing.	Sublimation of water from exposed plant tissues can, of course, be prevented by maintaining a snow cover until such time as losses may be replaced by plant. Management of the problem consists of nothing more than the preservation of helpful mulches of snow and other materials over plants.
Melting snow and ice may open water surfaces to air, permitting a buildup of exhausted oxygen resources in waters supporting valuable fish and associated animals. Snowbanks may delay melting of frozen water at soil surface until season is settled, avoiding losses due to rapid changes.	Melting speeds may be influenced by judicious planting of shade-producing crops, by use of mulches, or by removal of mulches. Measurement of snow accumulation in highlands may provide useful information in prediction of time and volume of possible flood waters produced by melting.	Floods may destroy great volumes of valuable top soil, as well as young growing crops. If delayed, they may influence annual crops of fish, water birds, or even the whole economy of a tract of agricultural land. Deposition of undue amounts of silt following floods may ruin a crop year.
The hardness of parts of a snow cover provides both conveniences and difficulties for wildlife, which, because of food and survival needs, must move through the snow. Such movements must be well-timed to avoid the traps of man and many other hazards, both natural and artificial.	Activities of man and other hunters are often governed by recognition of the fact that a snow crust makes escape or pursuit difficult or easy, depending largely on the qualifications of the animal involved. Many such stories—and their sequels—are recorded by tracks in the snow.	Changes in physical nature of water in and near snowbanks may affect the economy of living things that are close to the soil, partly buried, or that extend far above the soil and its blanket of snow. Management of plant cover is a most important aspect of snow-cover planning.
In Great Lakes region in fall, before snow accumulates, soil may freeze to a depth of 3 feet, and, if covered with snow, may continue frozen through winter. In areas with less snowfall, soil may freeze to depths of over 5 feet. Such conditions limit activities of animals that must burrow.	Anything that anchors a layer of air at a given level may be useful in wildlife management. Forests, grass-covered soils, mulches, cultivated soils, blankets of snow are all factors. The pelt of a fur-bearer is simply a portable blanket that permits its wearer movement denied fixed organisms.	The role of a snow cover in heat insulation is one of the most important performed by winter snowfall influencing not only plants and animals but determining in part the speed of the spring runoff and loss of topsoil by erosion, driving wind, and traffic of various kinds.
Compacting of snow and compacting of soils may affect the waterholding abilities of these substances. In dry-farming areas, fields may be rolled in spring partly to concentrate water around seeds. Similarly, paths, trails, and roads followed by man introduce problems in snow cover matters.	Heavy snowfalls may bend woody plants to the ground, leaving "roofed" areas into which animals may retreat and find shelter, food, and safety. By bending tops of rosebushes into early snowbanks, winterkill may be avoided; but danger of mouse damage may be increased. Man can help here.	Snow damage to ornamental trees may be great at times, and carelessly built dwellings, not designed for heavy snow conditions, may also suffer severely at times. Much trouble can be avoided by use of intelligent and appropriate designs that meet the needs of the locality involved.
Ice over ponds may be transparent, permitting light to reach underwater life which can carry on normal functions. A blanket of opaque snow may change the whole, stopping oxygen production of plants and permitting over production of deadly carbon dioxide, killing most underwater animals.	Dark cinders applied to snow covered roads absorb heat and accelerate melting of snow and clearing of roads. Roads may absorb or reflect light from beneath the snow, causing variation in ease of clearing highways for traffic. Colored snows are often due to organisms living on the snowbanks.	Managed light may be used to delay or accelerate melting of snow blanket, and is more efficient than manual effort. Where snow becomes packed on a highway, clearing may be more expensive than it would be under better lighted conditions. It may also delay thawing, acting as a mulch.

	DESCRIPTION	FACTORS INVOLVED
Transportation	Snow that has fallen to the ground may remain where it falls; but much of it may sooner or later shift its position because of wind, water movement, animal activity, or gravity. Some of it may be moved because of an unstable base—a floating log, piece of ice, or a moving animal.	In itself, the snow is largely inert; but any agency capable of changing wind or water direction or velocity can move the snow from one place to another. For the most part, this can be controlled by barriers like forests, snow fences, or structures that may be grown or erected.
Topography and the Snow Cover	Developments in snow cover are influenced profoundly by the topography of supporting ground, as well as by the nature of the blanket itself. Masses of snow seek equilibrium, and if unsupported by the masses of earth upon which they rest, may move until the pressures are adjusted.	The steeper the incline, the greater the tendency of snow cover on a slope to move, and the compactness and weight of the snow has a positive effect on subsequent events. Movement of a snow blanket down a slope may leave scars, and may destroy property. It may also sometimes be controlled.
Snow In and Above Water	Snow accumulations not only affect activities on earth under snowbanks but also affect conditions in water that is under the accumulations of snow. Such conditions may be at the same time physical and physiological in nature, and they may even be of importance occasionally.	Snow accumulated as slush in water may limit the movements of swimming animals, like muskrats, beyond their point of endurance, and result in death. Snow-clogged waterways at the edge of open water and stable shores may be semi-colloidal in nature, and capable of quick and dangerous changes.
Snow Sculpture	Accumulations of snow are subject to influences that change their shape, density, and other characteristics. By violence, winds may mold the snow surface and the temperature of moving adjacent air may modify the shape of a bank. Animals moving over the surface of a bank may change its shape.	Subsurfaces of snowbanks may be tunneled by animals seeking food or safety. Subsurfaces may be sculptured by the shifting weights of strata in the bank. Water may pour through a snowbank, changing its subsurface nature, cutting tunnels, and wearing or melting away the snow.
Time and Snow Blankets	Over the United States, the snow blanket annually averages from less than 1 inch to more than 800 inches, the snow lasting from less than a day to more than 150 days. These figures are reasonably consistent, and are within a framework of yearly temperatures between 125°F. and 50°F.	Frost-free periods vary from 90 days a year in the higher parts of the West, to the whole year in parts of Florida adjacent to the ocean. For the most part, the growing season ranges from 90 to 260 days; plants and dependent animals must be prepared to meet varying conditions over the year.
Extraneous Inorganic Materials	Any long-standing snowbank—like the accumulation of ice in a glacier—has much extraneous inorganic material with it. Material may be soot, slag, dust, mud, or other substances, brought in by wind, flood, or animals. This material has a significant effect on the life of a snowbank.	The effect of extraneous materials is largely dependent on the nature of the weather. The light-reflecting, heat absorbing qualities of the inorganic material, its weight and abrasive qualities, and its abundance and solvent qualities may materially and functionally affect the snow blanket.
Extraneous Plant Materials	There is a mutual relationship between plants and the snow blanket. This is true whether it concerns snow in motion or that which has been "fixed"; the plant materials may either be anchored or free. In snow blanket management, shade provided by plants offers planners a most valuable tool.	The slowing of winds by erect plants increases the build-up of snowbanks by reducing the snow-carrying ability of the wind, and their shade delays melting. Thus the risk of flood is lessened, and the soil is able to absorb melting snow, building up the water table and delaying drought.
Problems of Minute Animals on Snow	The 89th and 107th inserts of this series considered this topic in detail. Certain crane flies, stone flies, springtails, cankerworms, flies, bees, scale insects, and butterflies are often active during the time that snow covers the ground, and in a minor way they affect other organisms to some degree.	The short seasonal activities of some of the animals associated with snowbanks are rather remarkable. The snow cover and its host of little worlds and little years is completely unknown to many. A few days, or, at most, weeks, may encompass some of the life activities of such animals.
Problems of Extraneous Large Animals	Large animals find that problems associated with snow cover lie largely in a limitation of movement, in temperature moderation, in ability to get at food supply, and in ability to avoid being seen by enemies. Conditions change with size of the animal and depth of snow accumulation.	If the depth of the snow exceeds the length of an animal's legs, it may prevent freedom of movement to escape enemies and to get food, unless burrowing is possible. If weight of the animal, standing or running, can be supported by the crust of the snow, conditions of survival change.

WILDLIFE ROLE	MANAGEMENT	ECONOMICS
Generally, increasing the velocity of the element moving next to a snow accumulation accelerates snow movement, and decreasing the velocity slows such movement. Knowing this, we can anchor snow over soils that should not be frozen, can build up snows in areas needing water reserves.	Snow and ice crystals moving in air or water may have an abrasive effect on stationary objects, while snow in a fixed position may prevent such action from occurring. In some locations, snow may well be considered of significance with regard to these effects during the whole of the calendar year.	The slow movement of glaciers and rapid movement of avalanches both exert significant effects on the snow blanket over long and short time units, and greatly influence the economic status of an area. Even greater and more important are changes effected by movements of intermediate nature.
Animals, including man, may sometimes start avalanches by upsetting established balances, and may be destroyed by the violence of resulting disturbances. Whole communities of animals and men may thus be destroyed by slipping snow cover, but established woods may lessen danger.	Procedures recognized as of value in preventing soil erosion may be suggestive of those valuable in preventing damage by slipping snow cover. Highways, railroads, streams, dwellings and whole communities may be destroyed by snow slides. Miniature slides may be observed on roofs.	In a rolling terrain with an uneven surface, winds tend to wear down the more exposed points of snow and to fill in the valleys between. When the whole snow mass slips, violence may become sufficient to destroy valuable assets. It is important that means of regulating snow slides be considered.
Snow over waterways of fluctuating level may provide sanctuary for animals like mink, which can feed in safety on animals in distress. Even water running over normally dry earth —but under snowbanks—may create, in spring, a new, if temporary, world with its special problems.	The abrasive effect of snow and ice-clogged moving water may scour creek bottoms of plant and animal matter, freeing many small animals into the water to become prey for fish life. Such abrasion may also help to shape the stream bottoms, and even slowly widen and deepen a waterway.	Snow-covered ice limits light penetration and permits undue production of carbon dioxide, with an ensuing upset of the whole economy of a waterway, at least temporarily. Farm fishponds may well be so constructed that winds can sweep the ice free of snow to preserve underwater balance.
Heat from decaying organic material may melt a snowbank from beneath; warm air arising from a mouse's nest may melt a chimney of snow through a two-foot snow bank. A herd of deer may, by moving about, pack down snow to form an open shelter, with its attendant advantages and hazards.	The maintenance of open highways for commerce and pleasure involves the sculpture of snow in a large way. The management of snow on rooftops may involve a number of ingenious techniques. Still chiefly used, however, is the old-fashioned, but quite effective, traditional snow shovel.	Eskimos ingeniously make snow houses, or igloos, of snow blocks arranged in an incurving spiral, with thermal-trap entrances. In these they live safely and comfortably in the severest of weather. Seasoned campers sometimes bury themselves in the snow to avoid extreme conditions of cold.
Even in regions experiencing the greatest extremes of temperature and snowfall, many sensitive organisms survive in small areas that may not be greatly affected. Animals may survive difficult times by hibernation, by migration, by congregation, and often by sheer endurance in the face of hardships.	Freezing conditions may be necessary for the completion of the life cycle in some plants, and they provide an ideal background for many animals to reproduce and prosper. The seeds of a large number of plants will not germinate unless they have been subjected to freezing.	In general, the snow blanket serves a useful purpose in preventing the freezing of many plants and animals, in extending the season in which water is readily available, in reducing crises caused by excessive water or extreme temperatures, and perhaps in the elimination of weak animals.
All life is affected by the purity of the air with which it is associated, and snow banks reflect the purity of the air. This is obvious near cities and dusty fields. The snow near a coal-burning community differs greatly from that of the open country, and may be an index to air purity.	Downwind from bare dusty fields, the snow may appear muddy because of the windblown material accumulating there. This may provide an indication of snowbank anchoring qualities in preventing undesirable wind erosion. Mutual management roles of snow and inorganic materials are important.	Snow-covered roads may be kept clear by the use of slag, which not only helps vehicle traction but also accelerates melting of icy surfaces. Slag is merely coarser than the dust and soot that float freely in the average urban atmosphere, and offers a dark surface to absorb heat.
Animals profit by an accumulation of snow if they can burrow in it, as do mice. Plants provide a source of food for such animals, and the snow cover provides shelter from enemies. The way in which snow melts around the base of trees shows a definite relationship between snow and plants.	Surface snows are commonly bearers of such seeds and fruits as may be blown about during winter, and thus help in distribution. Particularly conspicuous may be the seeds and fruits of ash, hemlock, birch, maple, and weeds like Russian thistle, pigweeds, and similar winter bird-food plants.	Snowbanks, both over bare soil and over growing plants, may occasionally show differences. Such differences, however, may be due to a local movement of water under the snow. There is no doubt that snowbanks play an important role in the ecology of the plants that they cover
Minute animals of the snow may provide a food supply for some birds. However, among the snow fleas, for example, there are some like *Isotoma* that gorge in earliest spring on the [illegible] and other small plants. Others [illegible] and feed on equally [illegible]	Some snow fleas are dark, and the heat they absorb makes possible a remarkable existence in which they are frozen in the snow at night and become active when warmed by the day's sun. They may respire through body surfaces rather than through lungs, and may feed on pollen and similar material	Remarkable abundance of some snow animals of diminutive size may cause distressing pollution of maple sap being harvested for sugar, although this is usually ignored. Sprays may be applied early to control species that appear as snows vanish, and which may affect crops from woody plants
Problems connected with [illegible]	Snow accumulation provides an important world in which plant-destroying mice may prosper free from enemy attack. Fortunately, when spring snows vanish, migrating hawks and owls find them [illegible]	Many animals tend to congregate in time of deep snow, thus helping to keep game trails open. Congregation, however, increases burden on the food supply because of competition. Range cattle may be assisted by trail-breaking tractors that open up buried food supplies, saving them from death

nature IN THE SCHOOL

THE PROGRAMS AND TEXTBOOKS used in our schools today seem to attach little significance to such simple phenomena as snow blankets, which can "make or break" the farmer, the merchant, and many others.

Every year millions of people see the snowdrifts appear and disappear, without realizing that they are witnessing the operation of the natural water cycle—the sequence in which water vapor is precipitated to earth in liquid or solid form, only to be returned directly or indirectly to the atmosphere as water vapor.

It might be interesting to find out what results could be obtained from tables bearing on the relation between snowfall and local temperatures. Such tables need not be highly accurate to be reasonably significant. The student might make a chart consisting of eight steps, each representing a unit of five degrees—from zero to thirty-five degrees above zero, Fahrenheit. Use a stick, marked in inches, placed vertically in the ground in a sheltered place. Indicate on the chart the number of inches of snow accumulating at the different temperatures.

Does it seem that the heaviest snowfalls take place near zero, or near the freezing point of water? Are the big local snowfalls in the dead of winter, in the fall, or in the spring? Is there a basis for the saying that "it may be too cold to snow?"

CHART the temperatures of a number of snowbanks from measurements in the air just above the surface of the bank; at a point just beneath the crust; at a point a foot or more beneath the surface; and close to the ground under the snow. Try to explain the differences that may be noted during the operation. If there is a crust on the snow, and the sun is shining, is the snow under the crust ever warmer than the air above it?

How much difference in temperature can you find in one vertical inch of snow near the surface of the bank? Such a difference conceivably could have a bearing on a practical problem. If your airplane, for instance, came down for a crash-landing on a windswept glacier, would you be better off to stay in the unheated plane, or would it be more prudent to burrow into a snowdrift?

Using strips of cardboard a foot wide and a yard long, see if you can make a snowdrift form when the wind is blowing the snow. In competition with others, try to make a drift cover a marker a foot square when the marker is lying flat on the snow. The usefulness of an object in anchoring moving snow is important if the water to be released later is to be conserved.

Place a number of foot-square markers on the snow, and hold them in position with weights. Try markers of several different colors, to see if color in any way affects the manner or the speed with which the markers melt their way into a snowdrift.

The top of the snow cover, at certain times of year, may be sprinkled with the seeds and fruits of trees and other plants. Measure the distance from some of these seeds to the nearest plant that bears similar seeds or fruits. Notice whether a good snow crust helps or hinders the movement of plant parts, or if it helps seed dissemination in some respects and hinders it in others. Which kind of seeds or fruits are found farthest from the plants that bore them? Try to find some seed-bearing plant parts that move like "tumbleweeds," others that move because they are winged, and still others that are blown like dust over the crust of the snow.

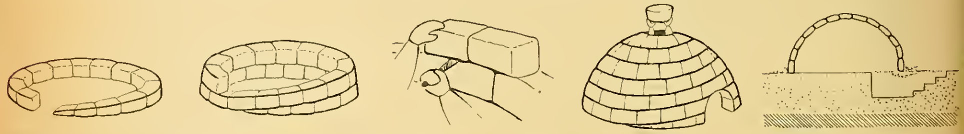
Make a record of the bird and mammal tracks found on the surface of a snowbank, and try to interpret the actions of the creature at the time the tracks were made. Note the degree to which larger and smaller animals can move across the snow crust without breaking through. Small-footed, heavy deer may have difficulty in the search for food or safety in the deep snow, while a relatively large-footed animal, such as a rabbit, moves across the snow with ease.

Find a place where a bird or mammal has burrowed into a snowbank, and explore the trail under the bank by moving the snow back. Does the trail of a mouse under a snowbank lead to a food supply? Is it likely that such an animal lives in a world of constant danger? An observant student needs no textbook to find the answers to such questions.

In a field partly covered with snow, try to determine how deeply the topsoil is frozen, and whether there is a variation in the depth of freezing between snow-covered and bare topsoil. On the basis of your findings, how does a snowbank help to protect plants?

NOTICE how frequently heavy snows bend down the branches of trees and shrubs, so that they form roofed areas in which birds and mammals may find shelter from severe weather conditions. What local animals are most likely to be benefited by such shelters? Do animals finding shelter in such areas ever feed on the bark of the plants that provide them with welcome shelter?

Make a snow house, or igloo, as suggested in the accompanying illustration, and test the temperature both inside and in the open air. Try sleeping at least one night in a properly constructed snow house in order to test its comfort. In making practical use of the snow blanket, the student will better appreciate the part it plays not only in his life, but in the lives of the animals and plants around him.



Igloo blocks are 18 inches long, 12 inches wide, and 6 inches thick, made by trampling snow until hard. Place blocks in a circle 5 feet across, leaning them to the center. Cut first four to slope, and on them start second layer from inside the house. Water will pack ice hard. As the igloo grows, make an entrance, which can be protected by a tunnel of blocks. Entrance should be below floor level, thus forming a thermal trap that prevents loss of warm air and admission of cold.

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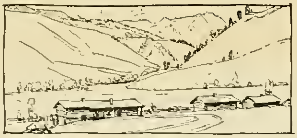

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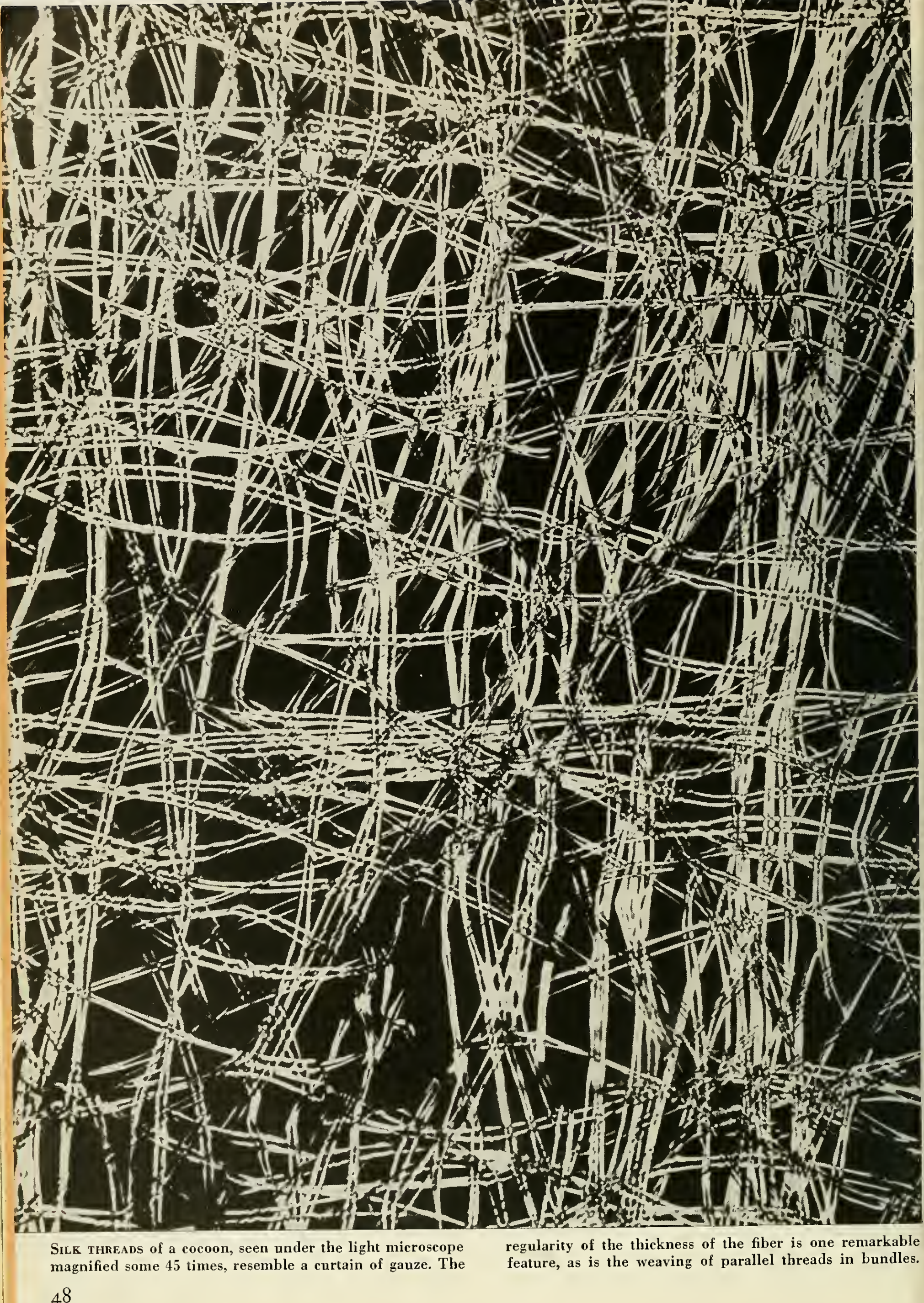
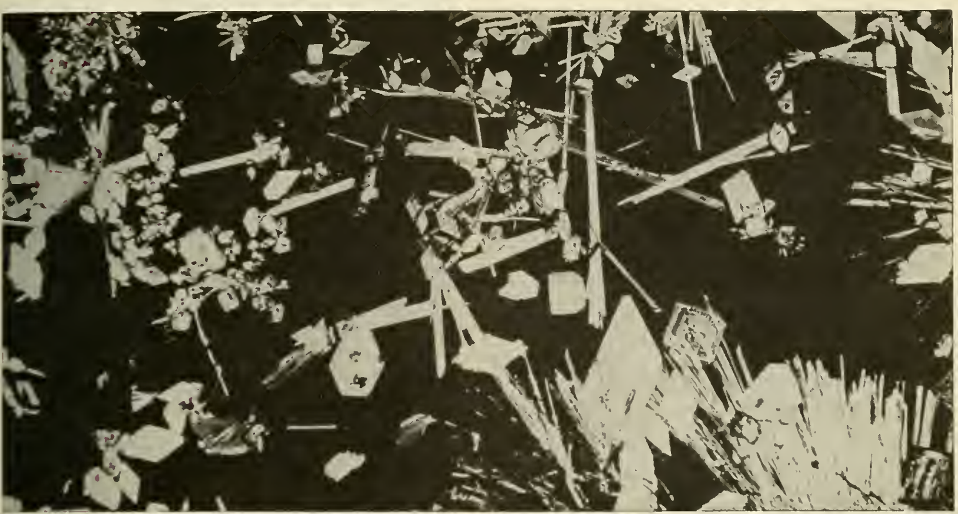


SILK THREADS of a cocoon, seen under the light microscope magnified some 45 times, resemble a curtain of gauze. The regularity of the thickness of the fiber is one remarkable feature, as is the weaving of parallel threads in bundles.



Crystals of salicylic acid are seen, at a magnification of 90, to be far less uniform than crystals are often thought to be. Molecules that comprise crystals are not grouped at random, but according to shape and electromagnetic forces.

STEPS TOWARD THE ATOM

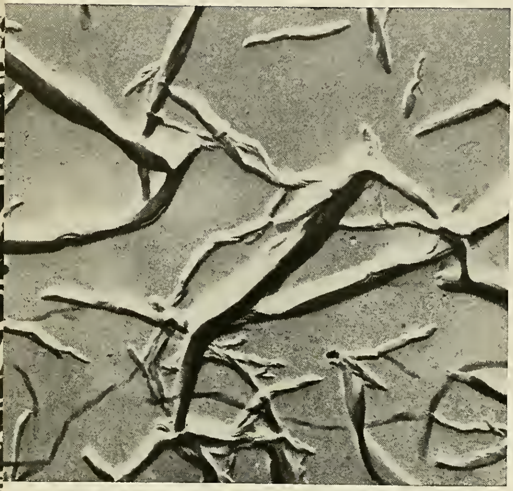
The most wonderful spectacle that human eyes can behold is the starry sky at night, yet the realm of the infinitely vast is only a part of the cosmos. In reality, the whole prodigious universe is made up of the infinitely small, composed of entities so minute as to be invisible.

Man seems set midway between the infinitely small and the infinitely great, so that the adventures awaiting explorers of the microcosm are at least as rich in promise as those that lure astronomers on. Thirty years ago, scientists would hardly have dared to hope that they would ever see those collections of atoms called molecules: yet today we can see not only molecules, but even the tracks of atoms and of subatomic particles.

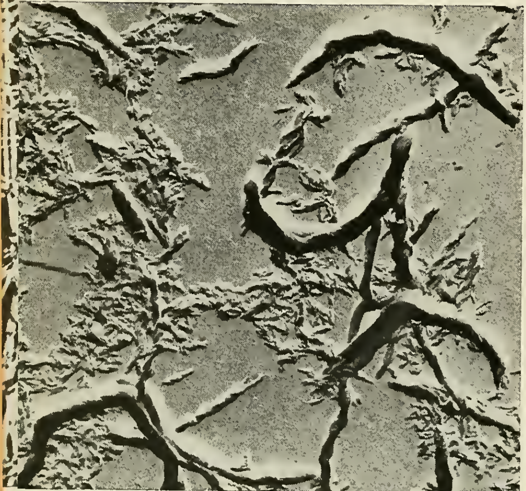
The photographs on these pages have been organized in a series of "steps," starting with larger objects and moving down to the microscopic and ultramicroscopic. In terms of units of measurement, they range from millimeters through microns to angstrom units, the latter named after the nineteenth-century Swedish physicist. Bacteria and metal crystals are of varying sizes round about the micron mark; viruses, on the other hand, are from one-tenth to one-hundredth that size in the case of animal viruses and one-thousandth in the case of vegetable viruses, which are measured in angstroms. Macromolecules, bundles of millions of atoms, tend to be smaller yet. The objects seen on this and the opposite page are relatively large, their magnifications ranging from about 50 times in the case of the cocoon threads at left to 1,500 for the zinc sulphide at right. As we move closer toward the atomic level, on the following pages, objects are shown in a series of photographs of increasing magnification.

Zinc sulphide was treated with hydrochloric acid and then washed to bring out the crystalline structure seen below.

The present article has been adapted from *The Thirteen Steps to the Atom*, by CHARLES-NOEL MARTIN. DR. MARTIN, a French physicist, began his studies at the University of Algiers and later took his doctorate at the Sorbonne. He did research at the Institut du Radium under Mme Joliot-Curie, and then, under Louis de Broglie, at the Institut Henri Poincaré. He is well known for both his scientific and popular publications. *The Thirteen Steps to the Atom* has been published in this country by Franklin Watts, Inc.

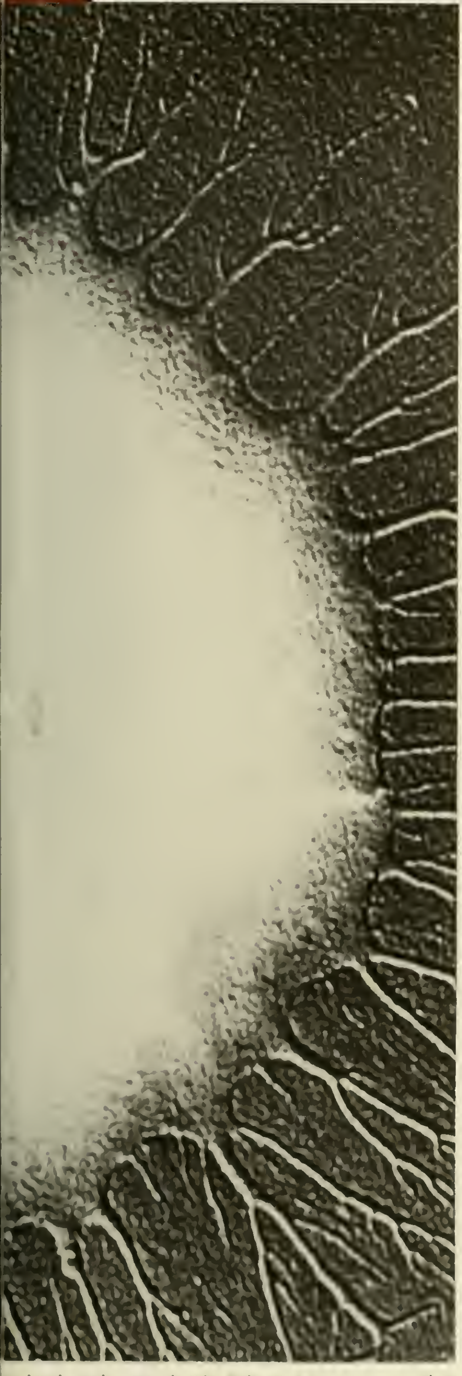


JEWEL-LIKE material shown here is automobile engine grease magnified 20,000 times. The grease above is still not used.

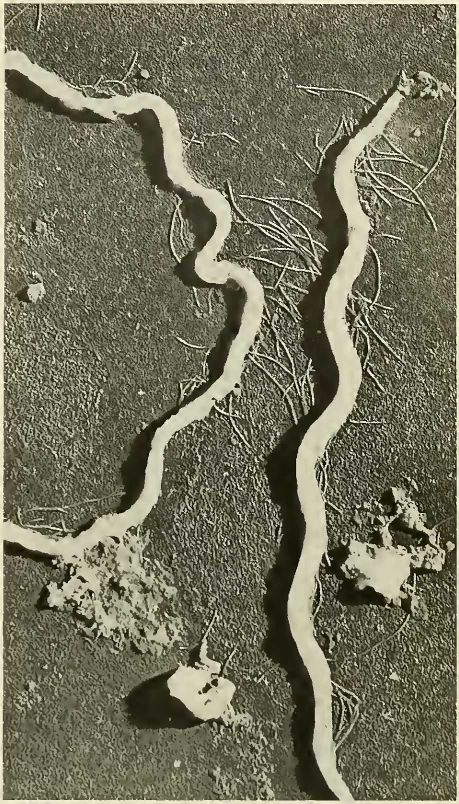


AFTER USE, some of the oleate fibers remain intact, while others have been torn, making lubrication less effective.

PARTICLE OF DNA (deoxyribonucleic acid) is like a radian sun. DNA is a huge molecule consisting of chains of simple

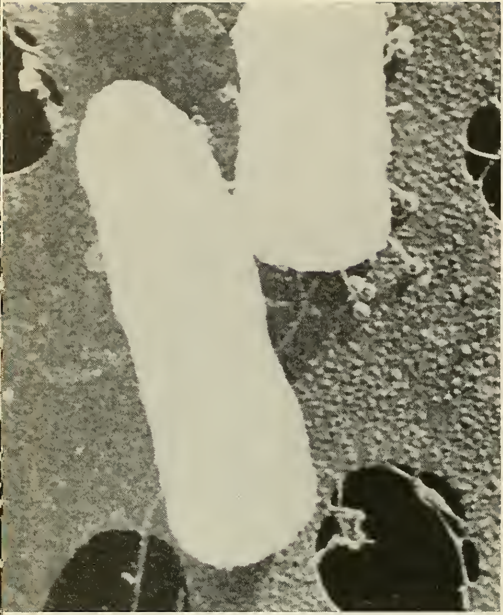


molecules. Above, under the influence of water vapor, they form branches, each containing a group of DNA chains.

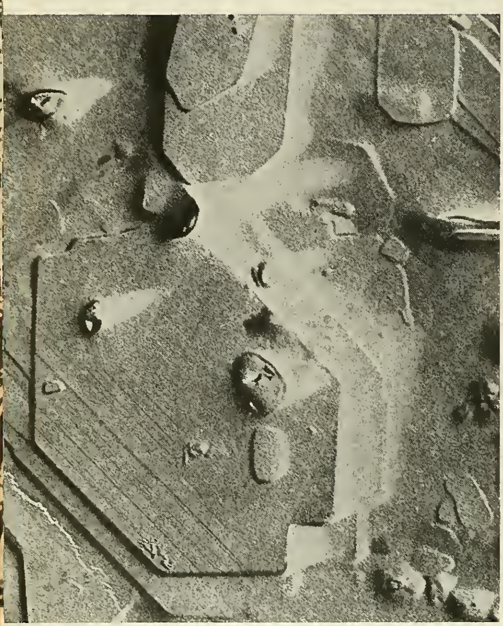


Recurrent fever microbes can be seen in light microscope, but reveal details only under electron instrument, as above.

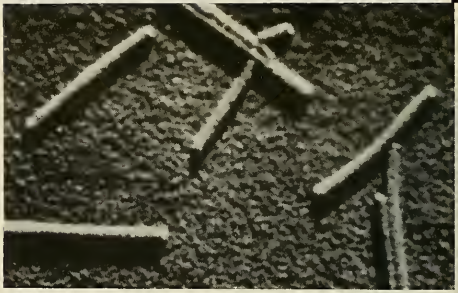
Ultrathin paper, magnified 7,600 times, includes diagonal cellulose fiber of original wood from which paper was made.



Bacteriophage viruses are seen clinging by their tails to the outer membrane of the white bacteria they are devouring.



Surface crystals of molybdenum oxide are shown magnified over 60,000 times. Impurities break up geometric pattern.

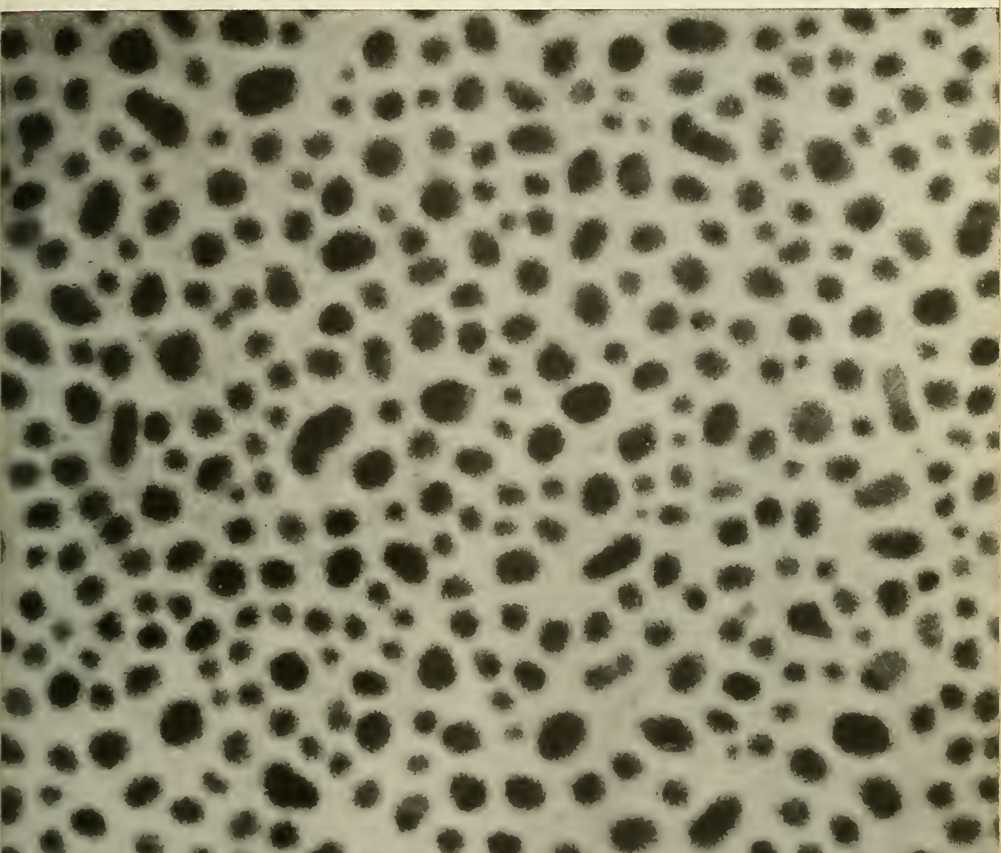


Tobacco mosaic virus is magnified 94,000 times. Unlike T-shaped bacteriophage, it has the form of a hexagonal rod.

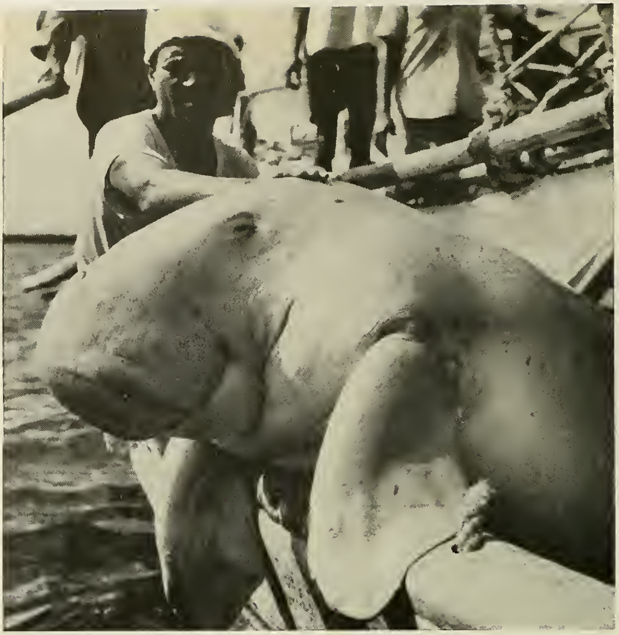
The power of an instrument to distinguish small details is called its resolving power. With the conventional light microscope, the limit of resolution is the smallest distance apart at which it is possible to distinguish two specks of light on a specimen. But the two specks of light are in fact two *sources* from which trains of light waves are emitted toward the eye of the observer, and for this reason optical microscopes cease to be able to distinguish details the dimensions of which are comparable to the length of light waves. For such very minute studies, the electron microscope is used instead.

In the electron microscope, a beam of electrons is fired at a specimen thin enough to allow the electrons to pass through it with some ease. If some parts of the specimen are thicker or denser than others, and thus more able to stop electrons, there will be variations in the proportion of an electron beam transmitted through different parts of the specimen. A photographic plate or a fluorescent screen placed behind the specimen records these variations. The superiority of the electron microscope over the optical instrument lies essentially in the fact that the wave length associated with a beam of fast electrons is far less than that of visible light, thus extending the possibilities of research concerning more minute objects.

The photographs on these two pages and the preceding two are examples of the magnifications to be obtained with new techniques. They range from a mere 7,600 times in the photographic paper seen on page 51 to 700,000 times for the particles of gold dust shown at right. Among the largest objects is the crystal of molybdenum oxide on the left, seen at some seven hundred times the magnification of the salicylic acid crystals on page 49. Of living forms, the dominant ones are the bacteria — about the same size as metal crystals, except in the lower ranges, which are smaller — and the viruses. Bacteria are visible under the light microscope, although their inner structure can only be seen clearly under an electron microscope. As for the viruses, in size they are to bacteria what bacteria are to large animals. Completely invisible under the light microscope, they fall into three types: the vegetable viruses; animal viruses, which are larger and more complex; and finally bacteriophages or T viruses, so called from their shape. The smallest objects represented here are the giant molecules, clusters of atoms numbering anything from around a hundred to over a million. These macromolecules also fall into three types: cellulose, which is the framework of vegetable matter but cannot be assimilated by man; protein, chemically the most important part of living matter; and, finally, molecules of DNA, which carry the hereditary characteristics of living species.



NEAR-ATOMIC PARTICLES of gold are magnified over 700,000 times in this photograph. Each grain of this extremely fine gold dust has only a few hundred or a few thousand atoms of gold, and is thus classed on the level of macromolecules.



Dugong leaning over rail of native dhow is the very image of a contented sea cow.

Taken by expedition for study, dugong surfaces in pool of a hotel in Mombasa.

SAILORS' SIREN

The dugong, rare marine mammal, gave rise to mermaid myth

By Joseph Curtis Moore

The similarity of location between the dugong's two nipples and man's must have inspired the earliest sailors of tropical waters to infer a likeness between the anterior half of the mermaid—actually, a female dugong—and woman. The animal's possession of a supposedly fishlike (really more whalelike) tail for propulsion would have fostered the further allegation that the posterior half of the mermaid was fish. All of this myth-making is very reasonable, but it is the writer's opinion—and the reader may feel free to disagree after examination of these photographs—that the further allegation of mermaid beauty has been possible to maintain only because, or where, the dugong has been an infrequent visitor.

The dugong is a sea cow that inhabits the shallow tropical and subtropical bays and lagoons of the Indian Ocean and the western Pacific Ocean, feeding upon the green grasses of these marine pastures. Being a mammal, it has some hair—scattered singly over most of the body—and possesses lungs, which it must refill with air by rising to the surface. The female gives milk to its single young, which is born alive under water and must swim to the surface for its very first breath of air.

Dugong meat is considered very good to eat, its oil excels other animal oils for use in cooking, and both products extraordinarily resist spoiling—a quality of great importance to man in the Tropics. Sea cows are also defenseless and man's greediness for their flesh has exceeded his desire to learn how these animals live. In most areas since the advent of science, man has kept dugongs so close to the edge of extinction that it has hardly been possible to study them. However, the Egyptian scientist Gohar, working in the Red Sea where dugongs were thought to be extinct, persisted for a period of thirteen years until he had captured fifteen individuals to examine. In each individual, he found the intestine full of a single, locally abundant, species of sea grass. He says that instead of haphazardly browsing along, as many terrestrial grazing mammals do, the dugong uproots whole plants of sea grass and piles them in stacks. When a number of these heaps are completed, the dugong is presumed to eat them more or less in order. Dr. Gohar speculates that this strange feeding habit may serve the dugong by allowing unwanted or even harmful animal life inhabiting the sea grass to creep out of it.

At the northeast end of the animal's geographic range, in Formosa, the dugong has received protection by being declared a national monument, although whether any still survive there remains in doubt. One wonders in what tropical maritime land the first successful effort will be made to bring the ecology of this fascinating and valuable sea mammal under study.

A Research Fellow at The American Museum's Department of Mammalogy, Dr. Moore admires marine mammals.

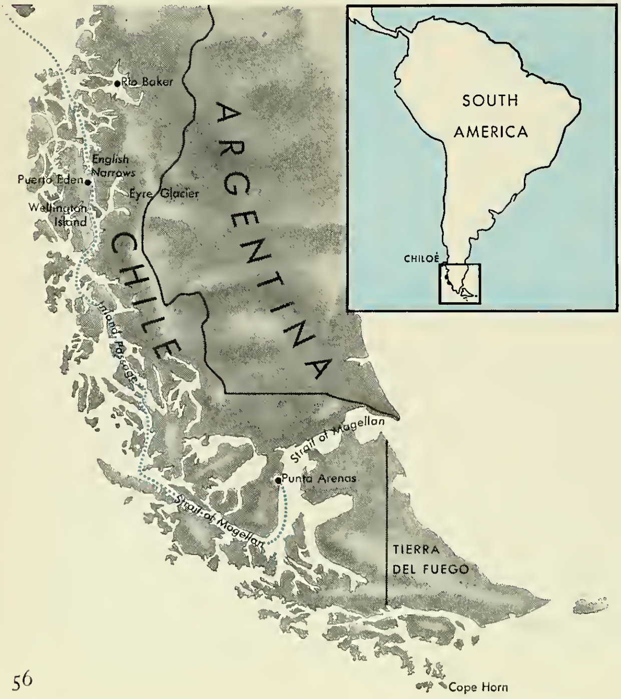
Man Against the Cold

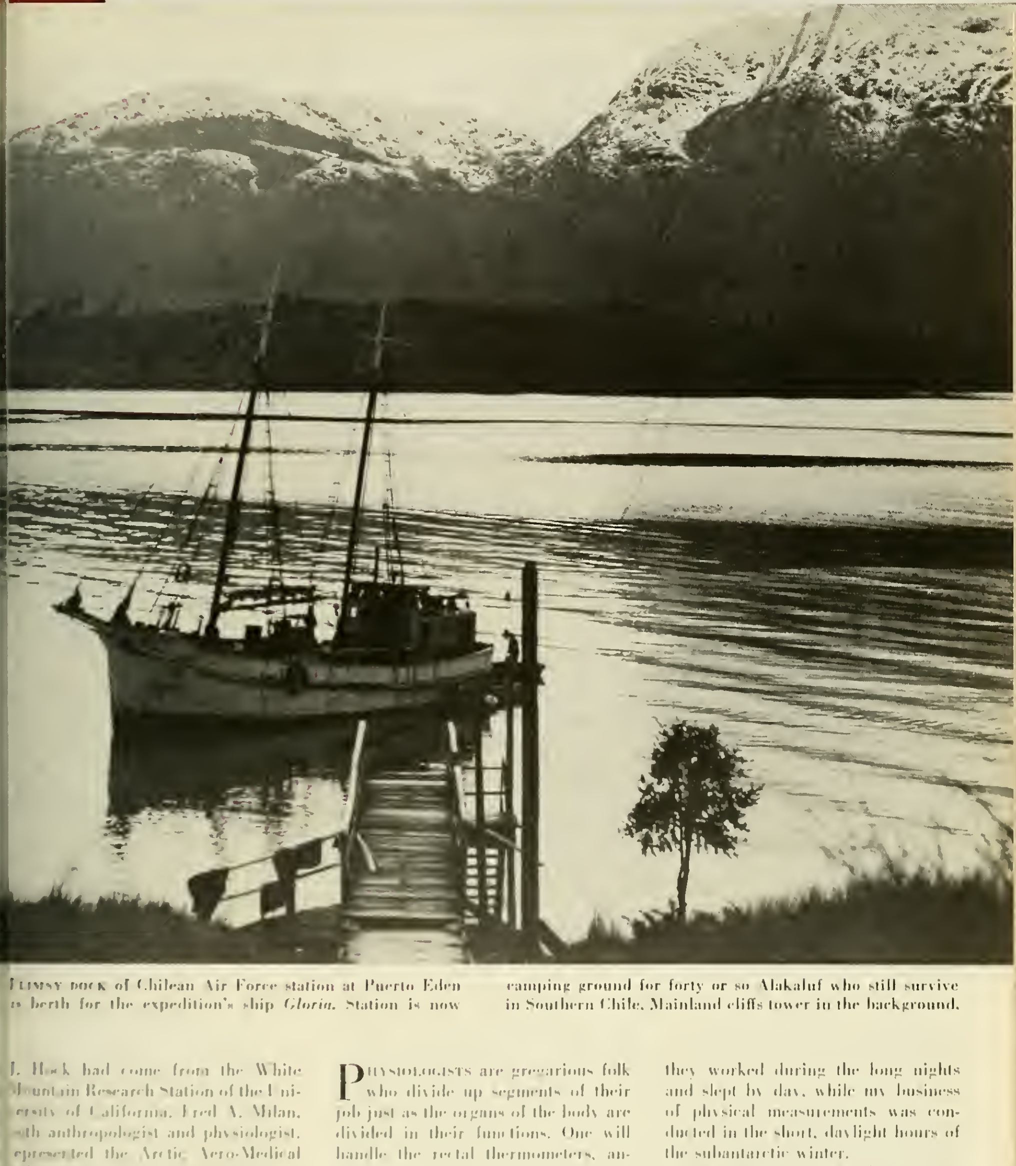
A visit to the last of the Alakaluf shows their adaptation to a subpolar climate

By Carleton S. Coon

The Gloria is a "barca," sixty feet of stout Chilean pine, as broad and as tough as a Hudson River tug. She has two short, thick masts, a stubby bowsprit, and a galley smokestack that telescopes when under sail. Below decks is a diesel engine that drives her through the turbulent, icy waters of Cape Horn at seven knots, or eleven with the help of sails and a following wind. Approaching the *Gloria* on the long dock at Punta Arenas, the world's most southerly seaport, the first living thing one hears or sees is Bua, the ship's dog — a tidy Scottish shepherd, friendly to man but unflinching foe to any dog that tries to come aboard.

I boarded the *Gloria* late in the summer of 1959 as the guest of a group of physiologists headed by Dr. T. H. Hammel, of the University of Pennsylvania Medical School. In co-operation with the Department of Anthropology of the University of Chile at Santiago. Hammel's party of nine was in pursuit of the Alakaluf, a dwindling tribe of Fuegian Indians that possesses an unusual capacity to resist cold weather. Don Alberto Medina and Luis Strozzi, M.D., represented the University of Chile. Per Scholander, from the Scripps Institute of Oceanography at La Jolla, was an old hand at physiological studies, as was K. Lange-Andersen, M.D., from Oslo. Robert V. Elsner was present from the University of Washington, Seattle, and Raymond


Rio Baker
ARGENTINA
English Narrows
Puerto Eden
Eyre Glacier
Wellington Island
CHILE
Inland Passage
Strait of Magellan
Punta Arenas
Strait of Magellan
TIERRA DEL FUEGO
Cope Horn
SOUTH AMERICA
CHILOÉ



LIMSY DOCK of Chilean Air Force station at Puerto Eden is berth for the expedition's ship *Gloria.* Station is now camping ground for forty or so Alakaluf who still survive in Southern Chile. Mainland cliffs tower in the background.

J. Hock had come from the White ountain Research Station of the University of California. Fred A. Milan, th anthropologist and physiologist, epresented the Arctic Aero-Medical aboratory at Ladd Air Force Base, airbanks, Alaska.

Hammel and Elsner, each of whom ad conjured up such an expedition dependently, had joined forces and sembled our party in Santiago in d August. Lange Andersen brought ith him from Norway a sort of land-cked bicycle that served to test mus-ular endurance—and many another eer shaped package filled the plane at carried us to Punta Arenas.

PHYSIOLOGISTS are gregarious folk who divide up segments of their job just as the organs of the body are divided in their functions. One will handle the rectal thermometers, another will watch a subject's oxygen intake and carbon dioxide output, and a third will check skin temperatures. What each physiologist in our group did on this trip is little known to me: they worked during the long nights and slept by day, while my business of physical measurements was conducted in the short, daylight hours of the subantarctic winter.

Whatever each of us did, the objective was the same. We had come to the Magellanic Islands to study the cold adaptation of the Alakaluf Indians. The U.S. Air Force, which footed most of the bill, wanted to know whether or not these Fuegians—among the ones described by Darwin during the voyage of the *Beagle*—were really different from the rest of us in their ability to tolerate cold and, if so, how and why. In today's threats of global war

Dr. Coon is a student of physique whose *Races of Europe* is a classic work of physical anthropology. Now in preparation is his further study, *Races of The World* (Alfred Knopf).

Low-lying smoke hovers over desolate Puerto Eden shore. Boat at lower right was made by Chilotes living on Chiloé Island off southern tip of Chilean coastal plain. Second boat is Alakaluf dugout with sea urchin fork at the stern.

fare, as well as in preparation for space travel, what a human organism can stand and how he stands it are items of strategic information.

When Magellan passed through the Strait that bears his name, he saw smoke rising from hundreds of fires on and near the shores of the great island to the south and the smaller, fringing islands. Hence the name "Fireland": Tierra del Fuego. The fuel for these fires was *Nothofagus*, an evergreen relative of the beech, which throws out great heat. Some of the smoke Magellan spied was leaking out of the roofs and doorways of domed huts, built of a framework of half-hoops covered with the skins of sea lions and sea otters; inside these huts, the temperature was sometimes as high as that of a New York hotel bedroom today. Other wisps of smoke came from the fires burning on clay hearths in skin or bark canoes.

Within the outer periphery of the campfire's radiation squatted a man, his wife (or wives), his children, and several browbeaten dogs. Some of these folk were naked, although smeared with grease and ochre; others wore small robes of sealskin or sea otter skin over their backs. These were the Fuegian Indians.

Before the white men entered and ruined their lives, the Fuegian Indians were divided into four tribes. On the main island of Tierra del Fuego lived a hunting people called the Ona — *Selknam* in their own language. They killed the native guanaco with bows and arrows, and wore robes of guanaco skin. At the very tip of the main island was a small tribe called Haush: these people disappeared before anyone had a chance to study them, but the Haush were probably related to the Ona. All along the shores of the southern border of Tierra del Fuego and on the neighboring small islands as far south as Cape Horn lived the Yaghan, or *Yamana* — so-called "Canoe Indians." It was they whom Darwin saw in Beagle Channel; Fuegia Basket and Jemmy Button were Yaghans; and i was among the Yaghans that the Rev Thomas Bridges devoted his life to hi work as a missionary.

The fourth tribe was the Alakalu — *Aweskar* in their own language They inhabited both sides of the Strai of Magellan and the shores of th fiords, channels, and seaways north t

he Taito Peninsula, and covered a uch larger territory than any of the ther tribes. No one knows how many lakaluf existed at their peak population, but six thousand is the figure ometimes given. The Alakaluf moved bout a good deal. Their middens — piles of clam, mussel, and other ells they left at temporary camp sites are shallow; those left by the Yag ns are deeper, showing that they led less nomadic life.

Alakaluf, or Alakalup, is a Yaghan rd meaning "People who use qua- shells for knives." And so they did. ith these shells they carved spear ints and harpoon heads out of halebone, and they also made four- ned spears out of cedar, with which ey collected sea urchins. Their noes were originally wooden frames covered with sea lion skin. When they got metal axes they made three-plank canoes and, finally, dugouts. Now the handful of surviving Alakaluf buy their boats from other people.

Until forty years ago, Alakaluf men wore their hair in a soup-bowl bob. Now they have Western-style haircuts. Within the present century, photographs were taken on board ships of Alakaluf men now alive or recently dead, walking about naked. Going naked but for a coat of grease is much healthier in wet weather than wearing someone's castoff jacket and trousers, letting them get soaking wet, and keeping them on in a heated hut. The Alakaluf could stand cold, but not the white man's colds and tuberculosis.

Darwin saw a Fuegian woman suckling a naked baby in a snowstorm, and I have seen naked Fuegian babies walking about in snow. Even today, Alakaluf women habitually go barefoot, wading in 40° F. water as they moor and cast off their boats, treading sleet and snow underfoot, and never seeming to mind the cold. Their feet and ankles seem built for this sort of treatment. Short toes; short, broad, square feet with a thick pad of fat on the arch; tubular ankles, three or four inches in diameter: these are designed

[illegible] [illegible] by water temperature that is barely 8° F. above the freezing point.

Alakaluf boy enjoys skin diving with mask brought by party to the Indians.

to equip Alakaluf women for their amphibious, subantarctic lives.

But such observations of gross morphology are too crude for physiologists. They must have temperatures to read, and quanta of gases and liquids to measure in millimeters and cubic centimeters. Hence all the paraphernalia we transshipped from airfield to dock and loaded aboard the *Gloria*. Such gear is strange to the field anthropologist: all that we need can often be loaded on a single mule. But we cannot study cold adaptation in such a way as to produce conclusive, scientific results. This is a task for a team of physiologists, with boxes full of metal, rubber, plastic, and glass gadgets for their various tests.

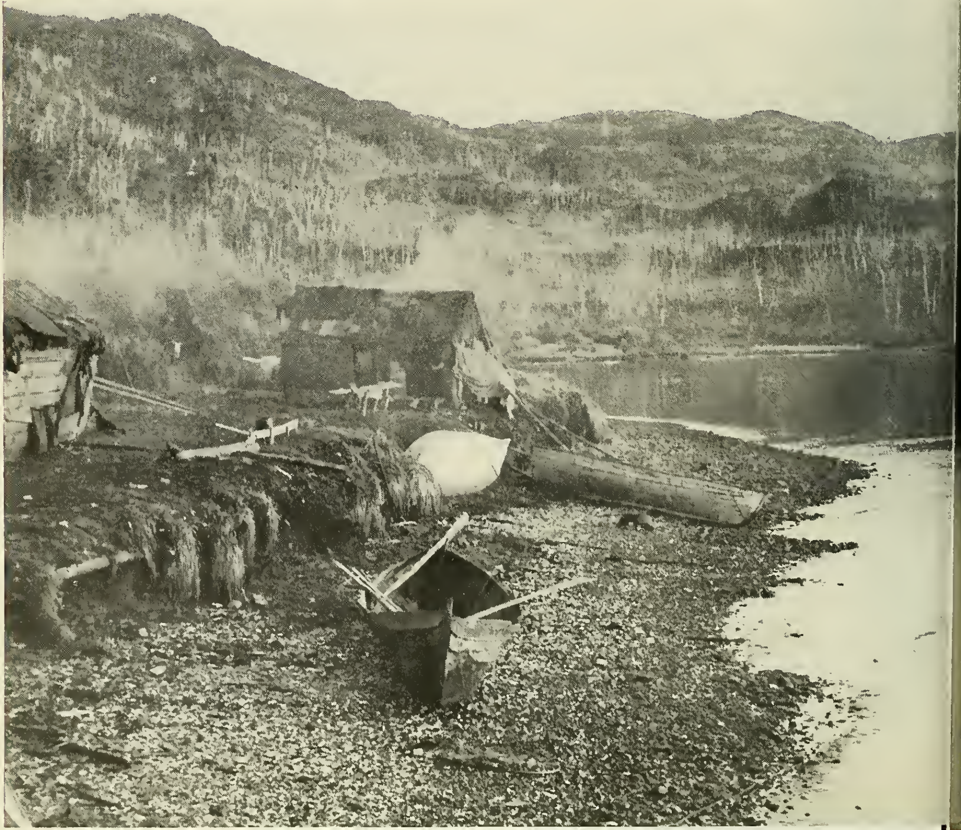
Like his crew of five, the Captain of the *Gloria* was a Chilote. The Chilotes are the inhabitants of the isle of Chiloé, off the southern end of the regularly inhabited coastal plain of Chile, and north of the myriad islands, steep-walled channels, and sea-reaching glaciers of Chile's almost uninhabited lower coast — the zone we were on our way to visit.

In early conquistador days, a company of noble folk from northern Spain settled in Chiloé, and established the foundation of a special human breed. First, the Spaniards absorbed the local Indians — Chona by name and probably related to the Alakaluf. Later, the product of this mixture absorbed an immigration of Araucanian Indians from the mainland — horsemen, cider-makers, and silversmiths. The result is a new subrace of man: short, square, extremely muscular, black-haired, red-cheeked, energetic, enterprising, and bright. Some Chilotes look enough like Indians for this Mongoloid touch to be noticed, but most do not. Captain Delgado, master of the *Gloria*, has no Indian features: he looks like a Basque — which probably many generations ago, his Spanish forebears had been.

The Chilotes have had a population explosion. Like Ireland, Chiloé is famous for potatoes, and its waters yield many fish. On a diet of potatoes, fish, and mutton, the Chilotes have bred rapidly, and have exported people. As this human product is cold-resistant, quick, and hard working, it now accounts for the majority of the population in the southern tip of South America, including both Magallanes Province in Chile, and Argentine Patagonia. In the latter, some 400,000 Chilotes retain Chilean citizenship.

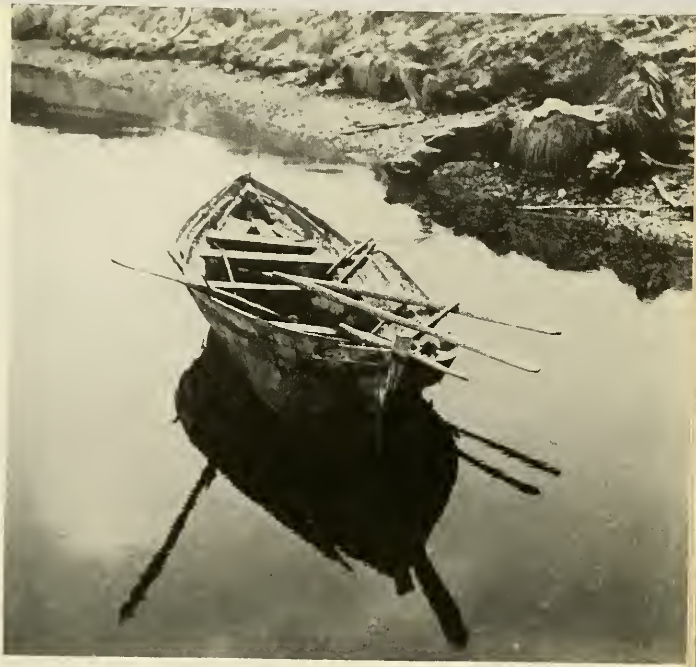
The *Gloria*'s cargo hold, a cavity thirty feet long, twenty feet wide, and some eight feet deep, was to be our quarters for the journey. In it, the day I first went aboard, a gang of carpenters was busy setting in bunks on the

Beach at camp is littered with mussel shells. On slopes in background is a stand of dead *Nothofagus* trees, to which Indians set fire in the dry season and so can fell without chopping in winter. Tree provides bulk of their firewood.



des and aft, and installing a two-burn- oil galley against the forward wall. aving seen the equipment and stores ır the nine of us and our cook and ɔok's helper. I wondered where it ɔuld all be stowed, but the cook, who ıd also seen the gear, reassured us, ıd he was right. Somehow, he found ɔom enough for the equipment, the ınned goods, and dry rations, and ırselves: in fact, exactly enough ɔom, with hardly space left over for a nall mouse. Our fresh meat, in the ırm of half-carcasses of beef and utton, was slung in the rigging, where teased the seagulls to near frenzy.

)UR cook's name was Adalberto Carcamo, and we simply called m the *jefe* [chief]. A short, fat, red- ıeeked Chilote of enormous energy, came along, he said, just for the easure of being on an expedition. He ıd been on many before. The *jefe* is a



DUGOUT with raised plank sides, still used on hunting trips, is propelled by oars staggered as in a racing shell. Women can handle them with precision.

rich man, the owner of a bar and restaurant at the foot of the Punta Arenas municipal pier. There he is both a ship's chandler and host to the transient seamen of many nations.

It was on a visit to the *jefe*'s establishment that I saw my first Fuegian Indian, a Yaghan who had come in from Navarino Island as a sailor. Medina, Strozzi, and I bewildered the poor young man with unexpected attention, and he blinked anxiously as the strobes of our cameras flashed. This meeting with a live Yaghan was a thrill I had long awaited, almost as great as when I first saw an Australian aborigine or a Philippine Pygmy.

The second Fuegian I saw was an eleven-year-old Alakaluf girl named Maria Theresa. She had been carried from her island home to a hospital at Punta Arenas, suffering from spinal tuberculosis. In an iron cot she lay, striking her forehead with a clenched fist, slowly, rhythmically, and dramatically, her features drawn into a lugubrious frown. When Dr. Strozzi told her that we would try to see her relatives, her face brightened and her fist unclenched. Her skin was light brown, the palms of her hands were dead white, and the hands large and well muscled, with beautifully formed nails. Her face was broad, her eyes set wide apart, and her features strikingly similar to those of an Ainu girl of the same age I had seen in Hokkaido two years before. Like that Ainu child, she had continuous hair from eyebrows to scalp on either side, and an exceedingly low hairline between. This hairy development left her little visible forehead. Her appearance, unusual for most American Indians, made me even more eager to see as many of the Alakaluf as I possibly could.

THE *Gloria* left port on the morning of August 25 and headed southwest in the Straits of Magellan, after a somewhat frenzied ceremony. Captain Delgado had appropriately raised a Chilean flag, and Dr. Lange-Andersen hoisted a Norwegian flag beside it. As six of the nine expedition members were Americans, something obviously was missing: Don Pedro Arendsen, the honorary Norwegian consul, soon supplied it. The Stars and Stripes took its place with the other national colors at the masthead, and we were off, to the cheers of a small, enthusiastic, and totally unexpected crowd.

At 5:15 P.M. we dropped anchor in

Bougainville Bay to check a leak in the fuel line. In this sheltered haven, near the tip of the continent, we saw cliffs behind a narrow, pebbly shore, and dense, almost tropical looking vegetation, with the false beech *Nothofagus* and a true cedar (related to the cedar of Lebanon but locally called cypress) as the dominant species, and with shrubs and ferns covering the ground. The scene was not unlike a miniature Japanese garden, exquisitely contrived and then magnified to a majestic scale. Hundreds of cormorants flew about, their speed exaggerated by their rapid wingbeat and craning necks. Among them Hock pointed out a loon.

The oil leak was fixed in short order and we were off again, passing tiny islands with storm-twisted trees, and leaving the snow-covered mountains of Tierra del Fuego in the background. This scenery continued to unfold all the next day until we were nearly exhausted by its beauty.

On the 26th, we passed a manned lighthouse—all the rest are automatic—between Manuel Rodriguez Island and the mainland. The lighthouse keeper waved warmly to us from the roof. A tanker passed us and we saw steamer ducks—those fat birds, incapable of flight, who propel themselves like side-wheel river boats by striking the water with their wings. A condor floated high overhead, and among the gulls glided an albatross. Before dusk we were visited by porpoises, which made everyone happy because Scholander is a world authority on their physiology and behavior, and he had just completed, in Punta Arenas, a letter to *Science* explaining how these brainy mammals ride, in defiance of dead body physics, on the bow waves of ships. This trick they proceeded to do for us almost as if they knew Scholander was aboard and wanted to entertain him.

At the end of the afternoon, we stopped in a cove to fetch fresh water, and there we found limpets, mussels, mandarin hats, and clams by the thousands, and collected a thousand or so mussels for supper. On the flatter parts of the shore, above high tide, stood the

COMMUNAL HOUSE at Puerto Eden camp seeps smoke at every crack. At left

CROWDED HUT of man at the right is the scene of one tape recording session.

half-hewn *Nothofagus* timber that ill become part of new hunting boat.

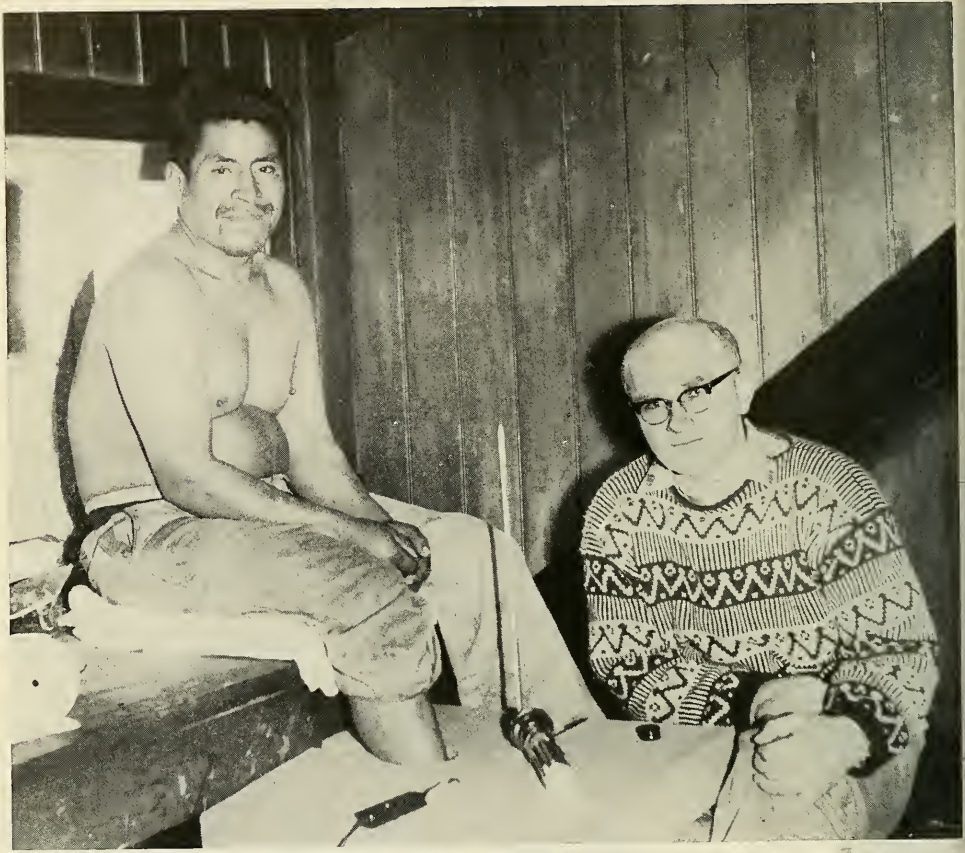
keletons of Alakaluf huts and extenive middens, bearing witness that this as a favorite Indian camping place. he Alakaluf leave these hut frames tanding between visits and carry way only the skin covers. While the nthropologists in our party inspected e hut frames and middens, Scholan- er, who is a botanist among his other ccomplishments, collected as many lant specimens as he had time for, in- luding holly, magnolia, and some- ing that looked like a tree cabbage.

LATE that same day we passed a grim, watery Calvary of ships, where wo freighters, freshly wrecked, had t yet settled. One stood on end, bow the sky, the other pointing into the channel at a 45° angle. From here on, the navigation became somewhat tricky and Captain Delgado could frequently be seen standing in the bow, where, like a football umpire in a hotly contested game, he passed dramatic arm and hand signals to the man in the wheelhouse.

We arrived at Puerto Eden on Wellington Island, our destination, in the declining light of day on August 29. We anchored in front of the Chilean Air Force house, the only carpenter-built, firm building between the lighthouse we had passed and Rio Baker, a distance of over 625 miles. This house is a two-storied frame structure of about ten rooms, originally built as a hotel for seaplane passengers flying between Santiago and Punta Arenas. Before the hotel was ready for its first guests, the Argentine government had suddenly removed its ban against Chilean planes flying over Patagonia—the ban that had inspired the hotel in the first place. Then Puerto Eden became a Chilean Air Force base and, at the same time, a rallying point and last haven for what was left of the Alakaluf.

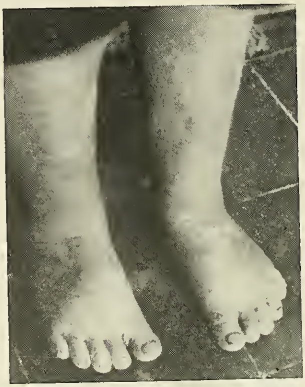
Many of these Indians stay at Puerto Eden most of the time, because the Chilean Air Force garrison feeds them when hungry, and gives them as much medical care as it is able. The medical orderly has, for example, eliminated venereal disease among the Alakaluf with penicillin injections. When an Indian needs hospitalization, he is sent

ATE is sucked through tube by woman ho helped to document Alakaluf life.

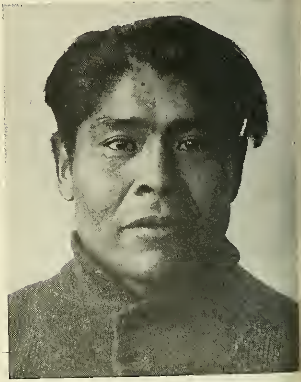


Laboratory was set up on second floor of the Chilean Air Force building, *above*, where Dr. Lange-Andersen is seen testing cold tolerance. The subject's foot is in ice water and thermocouple attached to skin records temperatures.

A constant and interested visitor to station was the so-called "fat girl."



Her fleshy ankles and thick feet are well suited for paddling in icy water.



Alakaluf male has typically strong, square face with brown eyes and hair.

n the next available ship to Punta renas. There is another advantage to his site, too. Puerto Eden is located in he lagoon just south of Angostura Ing-esa. the English Narrows. All ships of noderate draft that move north hrough this inland waterway—much almer than the open Pacific—have to top at Puerto Eden to await high tide, nless they arrive at that exact time. Vhile waiting at anchor. these vessels re invaded by two or three boatloads f Alakaluf. mostly women and chil-ren, who swarm aboard to squat, nutely pathetic. by the doors and atchways. They offer baskets and toy ark canoes (the latter modeled after hose of the Yaghans and not their wn) in exchange for clothing. food, igarettes. and forbidden liquor. They lso beg when barter fails.

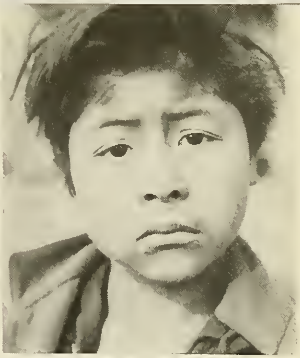
WHEN we first saw Puerto Eden. the beach was covered with mol-usk shells. and on it were drawn up ree or four dugout canoes. old and in oor shape. On the bank behind stood ur newly built plank houses. covered ith skins and seeping smoke, and be-ind the most distant house rested fty-odd drums of high octane gaso-ne. A small, wooden pier reached the annel. and on it stood our reception mmittee, consisting of three of the ur Chilean Air Force personnel at e base—a corporal. the cook. and the edical orderly. The commander. a rgeant. was in the house. on duty in e station's radio room.

These four men were to be our hosts r over a month. To Hammel and his llow physiologists they turned over most of their quarters, in which work was to go on all night: they installed the *jefe* in their own kitchen, and let me measure the Alakaluf in their parlor, and never a murmur of discord or a grumble of hurt feelings was heard by any of our party.

Once ashore. we were disappointed to find only five adult males. out of a total population of forty-nine Alakaluf, in the camp. One. Pancho. was ancient and bedridden. Another. who called himself Alessandri after the current president of Chile (he had formerly been Alejandro). had tuberculosis. A third. Enrique, had suffered a crippling injury to one hip and leg in his youth. by falling off a cliff while robbing birds' nests. Only two, Lucho (Luis) Molinari and José Lopez, were present and whole. Six other men were off in their longboats hunting sea otters. but exactly where no one knew.

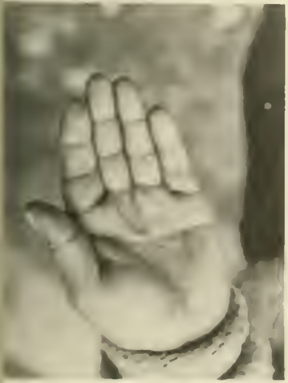
Because these three men. Lucho, José. and. in a pinch. Enrique, were not an adequate sample. Hammel immediately applied by radio to the Chilean Navy for permission (duly granted) to search the fiords north of us for the otter hunters and to bring them back to Puerto Eden.

Hammel. Elsner. and the other physiologists set up their laboratory in the second story of the Chilean Air Force building. A tent. below. was connected to the lab by tubes and wires run through a window. Their first volunteer was Lucho. for he was needed to guide us to the otter hunters. The physiologists' subject spent the night on a cot in the outdoor tent. under a light blanket and with a plastic "spaceman" hood over his head, a rectal thermometer in place. and eight thermocouples cemented to various spots on his skin. All night long the observers sat in their second-story laboratory, reading gauges. mixing magic brews. and in general doing things as mysterious to me as to the Alakaluf.



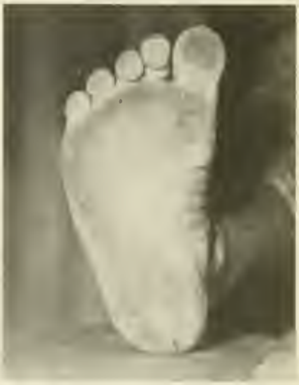
HAIR of children grows so low on the forehead it converges with eyebrows.

Once they wired Lucho and had him swim for eight minutes in the icy water, recording his internal and external temperatures from instruments on the shore. He came out of the water dripping. but not shivering. Lange-Andersen got all his subjects to grind away on his stationary bicycle, and downstairs I eventually measured all the men except the bedridden Pancho. taking not only weight and the conventional anthropometric constants but also the dimensions needed for calculating skin surface area. Elsner. among other things. measured fat folds on various parts of the body.



is RING FINGER is longer than is the dex finger—a common Alakaluf trait.

LOVE SONGS and tribal tales told by this old woman were recorded on tape.



HER BROAD, sturdy foot has formation much like prints left by Neanderthals.

Dogs accompany men on their hunts for both sea otter and nutria, chasing the animals into rock crevices on the beach so they can be speared easily. Like their masters, the do seem impervious to the cold water, and often swim to shor

Leaving the physiologists at work on the Alakaluf in camp, we boarded the *Gloria* a few days later and set out northward through the English Narrows into a labyrinth waterway, watching every minute for the otter hunters. Clad in Chilean replicas of Mr. Frost's Gloucester oilskins, our Alakaluf guide, Lucho, stood like a rubber figurehead throughout the day, scanning the misty waters for any sight of the boats. Each night we anchored in tiny, breathless coves, some still unnamed, but known of old to Captain Delgado. In them we went ashore for water and rowed about in the ship's boat to shoot ducks. Everywhere the dense foliage—with ferns and bright red berries under the trees—gave the shore line the look of a *douanier* Rousseau primitive painting—a look of the Tropics in temperatures only a degree or two above freezing, when not a degree or two below.

Each day, we cruised about a maze of inlets and channels between islands, in waters for which we had no charts. On September 5, we stopped at Vargas Island to pick up a one-eyed, half-Araucanian woodcutter who had been living alone with his dog, cutting "cypress." As he had spoken to no human being for seven months, he was naturally bubbling over with conversation. He came aboard at 4:30 P.M. and brought us luck. Less than an hour later, we rounded a cape of the same island to see two boats just leaving shingly beach. They held six men, woman, a boy, and nine dogs. Lo cheers rose from the deck of the *Glori* and even Lucho smiled.

The otter hunters were weari good Western clothing, including se eral pieces of formal attire, and we speaking to each other in Spanish we approached. As soon as they s Lucho's beaming face, they shifted Alakaluf. One young man, Carlos, w obviously the leader and all but one the other men were older. The wom —a small, elegant creature—had curious visage. Her upper face, incl ing her eyes, nose, and cheekbon was small and delicate but her ja

outh, and teeth were very large. Her ame was Lola and she had charge of e dogs. The boy of the party was rlito. The other men were Carlos' other, Virjilio, Manuel Lopez (José pez' brother), Manuel and Julio [illegible], and Francisco.

THESE men were younger and more vigorous than their tribesmen k at Puerto Eden. Except for Vir- they were wearing clothing ght new to fit them, instead of -offs. Their vessels were two new ker-built Chilote longboats, pro- led by oars, from which rose the ely stench of ripe sea lion meat and her slightly putrid proteins that I

could not identify. The hunt was over and the men were ready to go home.

We cast them a line and towed them into Rio Baker, the southernmost settlement of the Chilean mainland north of Magallanes Province. Except for Puerto Eden and a few woodcutters' huts, the intervening stretch is uninhabited. Here we spent the night, bought an ox to add to our meat supply, hung it high, hoisted the two longboats on deck—Lola and the dogs staying in one boat, away from Bua—and we were off, arriving at Puerto Eden with a following wind and tide, on the afternoon of September 7.

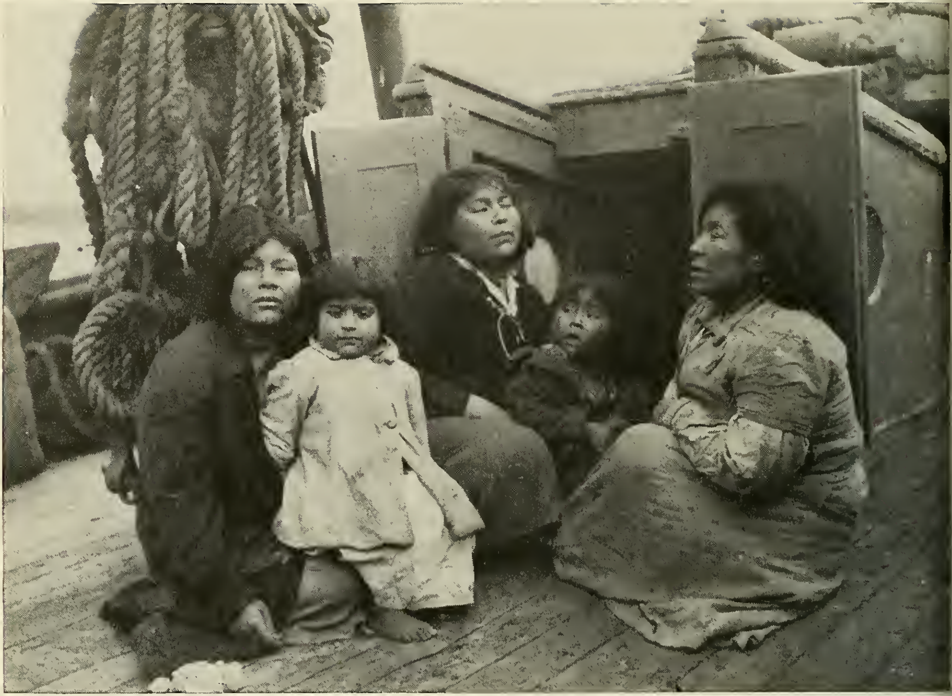
DOWN in the huts—during the next ten days—Medina and Strozzi and I, when I was able to join them, collected an Alakaluf vocabulary from various informants, particularly from Alessandri and from Margherita Canales, a one-eyed, middle-aged woman of great presence and charm, who sang ancient love songs for our tape recorders. Had we given them liquor, I was told, they might have forgotten the dreary present enough to have performed their ancient dances, imitating various birds and sea mammals with startling fidelity. But liquor is forbidden the Alakaluf by the Chilean government, and all we got was song.

The results of our investigations may be summarized under three headings: physiology, physical anthropology, and cultural anthropology.

Our physiologists found that their subjects are indeed cold-adapted. When they slept with little covering at 0° to 5° C., their metabolic rate remained high throughout the night (their basal metabolism being 150–200 per cent of the Dubois basal metabolic rate for white men of their height and weight). The Alakaluf men not only maintained a normal internal body temperature but also radiated heat through their extremities. White men also lose heat through their extremities but suffer a lowering of core temperature under similar circumstances. Australian aborigines, also studied by Scholander, Hammel, and J. S. Hart of Canada, maintain their core temperatures but lose less heat than either Indians or whites through their extremities because of a heat-transfer from arteries to veins in their upper arms and thighs.

From the physical anthropological point of view, this information indicates that ancestral American Indians, similar to the Alakaluf, could have walked from Asia to Alaska over the Bering land bridge at any time when the sea level was low enough and the

HIDDEN under skins on hut roof is a carcass of a huemul. Hunting of this rare, local deer is forbidden, but a few are killed each year by Alakaluf.



Women and children, in a sad but familiar ritual, crouch piteously at the hatchway of the *Gloria*, waiting for food to be given them. They swarm aboard all ships that stop at Puerto Eden until the tide rises in the English Narrows.

land bridge climate was comparable to that of present-day Tierra del Fuego. All such Indians would have needed was fire, a crude cutting tool, and the ability to build simple huts. America could have been first invaded at any suitable phase of the Wisconsian glaciation. When it actually *was* invaded must be settled by archeologists.

Racially the Alakaluf are fully *sapiens* Mongoloids. Some have heavy brow ridges, large teeth with five- and six-cusped molars, and very large hands, with long ring and shorter index fingers. Most have skins as light as Japanese or brunet Europeans, but they also have blue pigment spots on their backs above the sacrum and on their gums, as well as blue genitals. Their eyes are mostly light brown, their hair dark brown. The women's hair is usually red-brown, and probably bleached through diving. All of the men over twenty-five or so had beards, and some wore mustaches. Enrique had hair on his chest and back, and most of them had hair on their legs. The Alakaluf are about as hairy as the Japanese.

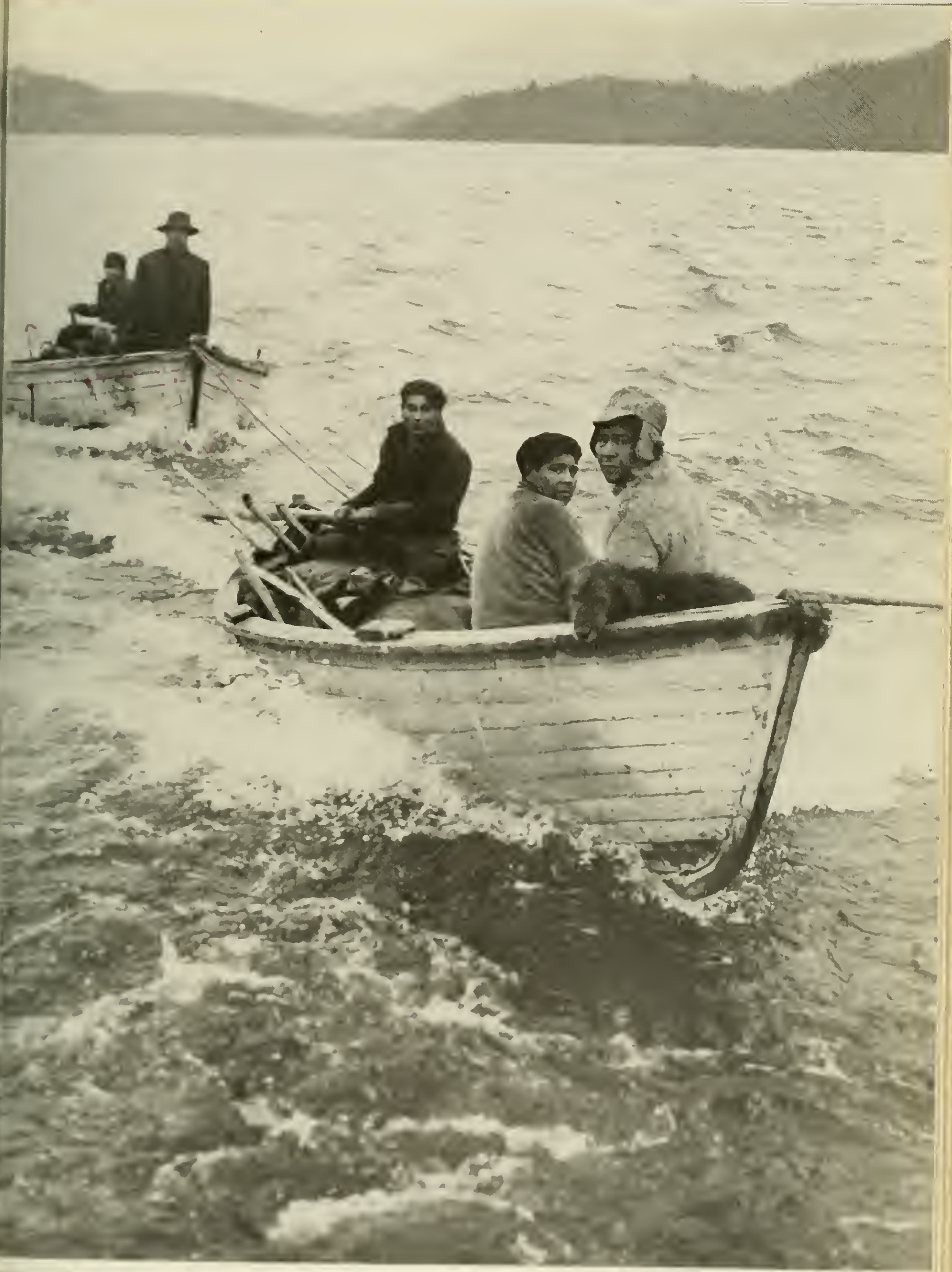
The mean weight of the men is 142 lbs., the mean height, 5′ 3″. They have big bodies, short necks, long arms, and short legs. Their heads and faces are both long and large. In other words, they look about as the first Indians to reach America could have looked, particularly if a little of what later produced the Ainu was added on the way.

Culturally, there is less to say. Ethnographic field work takes more time than basal metabolism measurements or anthropometry. A report on the trip's cultural findings is Dr. Medina's share of the work. He and Dr. Strozzi collected a vocabulary of many hundreds of words, some of which—like Bushman and Hottentot words and like the neighboring Ona language—are pronounced with clicks.

The Alakaluf have different words for father's father and mother's father, but one word for both grandmothers, which suggests that the grandmothers were sisters or cousins. Who marries whom and who feeds whom—an important point in such food-gathering societies—I do not know, but it was clea that much remarrying took place afte widowing and divorce. Continence i the young was not deemed a virtue Most deaths were caused either b drowning or by violence.

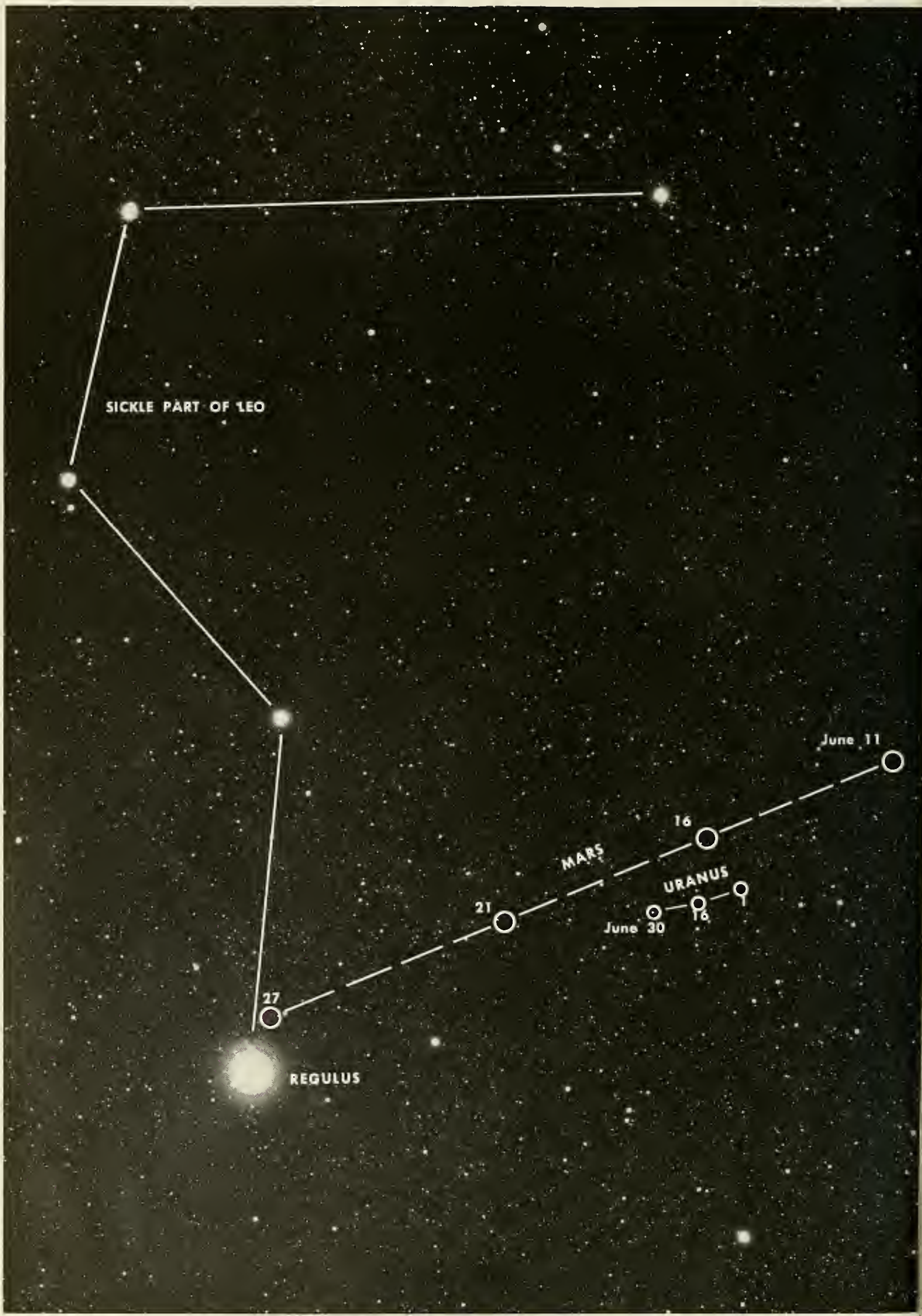
Of more immediate importance tha these meager notes is the fact that th survival of the Alakaluf without mix ture depends largely on the future o three young women. One of these wa pregnant by a Chilean during our sc journ, while another, Theresa, had le her husband and showed no inclin tion for further marriage or great hop of reproduction.

Much more serious is the fact tha Alakaluf culture—which cannot studied in a few short weeks—will soo become extinct. To all intents and pu poses, the fine details of this Fuegia culture will die with Alessandri an Margharita Canales—one of whom ha tuberculosis and the other one eye.



NGBOATS in tandem, carrying otter hunters, were towed Rio Baker, and later hoisted to the deck of the *Gloria*.

Problem for scientists lay in finding large enough number of Alakaluf males to make study measurements significant.


SICKLE PART OF LEO
June 11
16
MARS
URANUS
21
June 30
16
27
REGULUS

CELESTIAL EVENTS

listing of astronomical occurrences for the first half of 1961

By K. L. Franklin

JANUARY

January 2: The earth is closest to the sun today, a dis- nce of 91.4 million miles.

January 3: In the early morning hours, the Quadrantid eteor shower makes its annual appearance. A single ob- rver could see about forty meteors an hour at the peak of e shower were it not that the light of the nearly full moon ill interfere with the fainter streaks.

January 16: New moon occurs about 4:30 p.m., EST, d, about two hours later, the moon is closest to the earth, perigee. This combination will result in exceptionally gh and low tides for a few hours.

January 29: Venus is farthest east of the sun today, so will remain in the sky for about three hours after the sun ts, being the Evening Star until April.

FEBRUARY

February 15: A total eclipse of the sun occurs today, the th passing across France, northern Italy, Yugoslavia, umania, and the Crimea, and on into Siberia.

February 18: Jupiter is south of Saturn (by about half e moon's diameter) in the constellation of Sagittarius. oth are visible in the eastern sky before dawn, the brighter the pair being Jupiter. Although they appear very close the sky, Jupiter is 554 million miles from the earth and turn, 1,008 million miles away.

February 22: About 2:30 p.m., EST, the moon occults e star Aldebaran. Since this is during the afternoon, tele- opes will be needed to observe the event.

MARCH

March 2: A partial eclipse of the moon noticeably be- ns at 6:52 a.m., EST, and ends at 10:05 a.m., EST. The oon will have set for much of the eastern United States fore this eclipse begins, but Westerners can see a sub- antial part of the eclipse before moonset.

March 5: Venus is as bright as it will be this season— agnitude −4.3. Only the sun and the moon are brighter.

March 20: Spring begins in the Northern Hemisphere 3:32 p.m., EST, the same time that Autumn begins in Southern Hemisphere. The sun is directly above the rth's Equator at a point in the Pacific Ocean about 1,000 es north of Pitcairn Island.

March 21: About 11 p.m., EST, the moon occults Alde- ran again. The event will be interesting to watch, for first magnitude star will seem to vanish instantaneously the dark eastern limb of the first quarter moon interrupts ht rays from the star.

APRIL

April 11: Venus, which was so bright in the western sky t six weeks ago, is now between the earth and the sun, ing rapidly into the morning sky. At inferior conjunc- Venus is closest to the earth today—26.3 million miles ay. The nearest that Venus can approach the earth is st under 25 million miles.

April 21: Just before midnight, tonight, Mars can be seen appearing as a first magnitude star, about five degrees north of the first quarter moon, in the constellation Gemini. Each month, these two will pass nearer and nearer to each other until July, when observers in Mexico and eastern Asia will see the moon occult the planet.

April 30: At 2 a.m., this morning, much of the east coast of the United States adopts Eastern Daylight Time. Set your clocks *ahead* one hour.

MAY

May 16: Venus, now the Morning Star, has reached magnitude —4.2, as bright as it will be for sixteen months.

May 21: About an hour after sunset, for the next few evenings, look low into the northwestern sky, above the point where the sun has set. The bright object you will see is elusive Mercury, the planet closest to the sun. After these few evenings, Mercury will gradually fade in the twilight sky. This planet is rarely easy to see and now is a particularly favorable time to make the attempt.

JUNE

June 16: This evening, Uranus—appearing as a sixth magnitude star—can be found about one lunar diameter south of Mars. Bright Mars serves as a useful guide to viewing the first of the outer family of planets to be discovered in our solar system. A telescope or binoculars will be needed to observe Uranus easily. To make certain that you see it, make a map of the scene (illustration, *left*) and compare it with what you see for several evenings. The object that shifts relative position from night to night is Uranus. A sharp eye on a dark night can see Uranus distinctly, although the planet is over 1.75 billion miles distant from the earth at this time of the year.

Discovered accidentally by Sir William Herschel in 1781, by much the same method of relative motion observation you can use, Uranus was proved to be a planet by a later determination of its orbit around the sun. Deviations from the predicted path aroused suspicions of the existence of a still more distant body disturbing Uranus. As a result of mathematical investigations, this body—Neptune—was found in 1846. Similar deviations in Neptune's calculated path led to the discovery of Pluto—which has an average distance from the sun of nearly 4 billion miles—in 1930. Thus, Herschel's keen observations ultimately resulted in a quadrupling of the size of the solar system.

June 21: At 11:30 a.m., EDT, Summer arrives in the Northern Hemisphere, and Winter takes over the south of the Equator. This is the Summer Solstice.

June 27: Mars is less than a degree north of Regulus, the brightest star in the constellation Leo.

Dr. Franklin of The American Museum-Hayden Planetarium prepares this summary each six months.

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NATURAL HISTORY MAGAZINE
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ERCHED ON TWIGS, male *Hyla faber* tree frogs peer into e darkness from their usual arboreal surroundings. Frogs descend, however, in order to build the circular, panlike nests in which they mate and where their eggs are spawned.

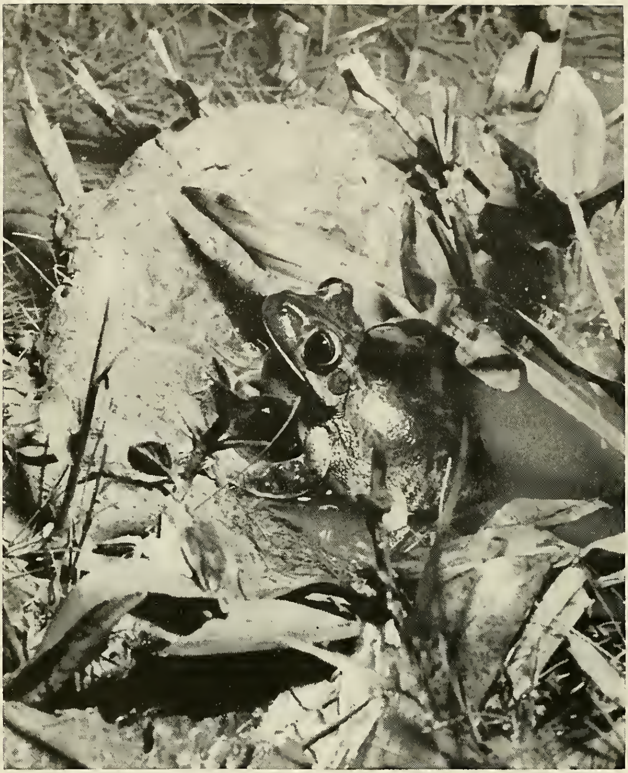
Mating of Hyla faber

Male makes a nest and will battle for it

By BERTHA LUTZ

A FROG'S VOICE that sounded like a hammer striking an anvil star-
d the naturalist, Prince Maximilian
Wied Neuwied, during a trip one
dred and forty-five years ago to
e Fazenda do Aga, near the Itapem-
im River, in the Brazilian province
f Espirito Santo. The Prince heard
e sound at nightfall coming from
e marsh near the house in which he
s staying. He took his first speci-
ens of the frog much later, however,
r the Rio das Contas, in Bahia.
e referred to the new species, *Hyla*
ber by its popular name *ferreiro*, or

CIRCULAR NESTS of three *Hyla faber* are located close together on a small island in the *Açude da Solidão*. Each nest is constructed by male frog only.



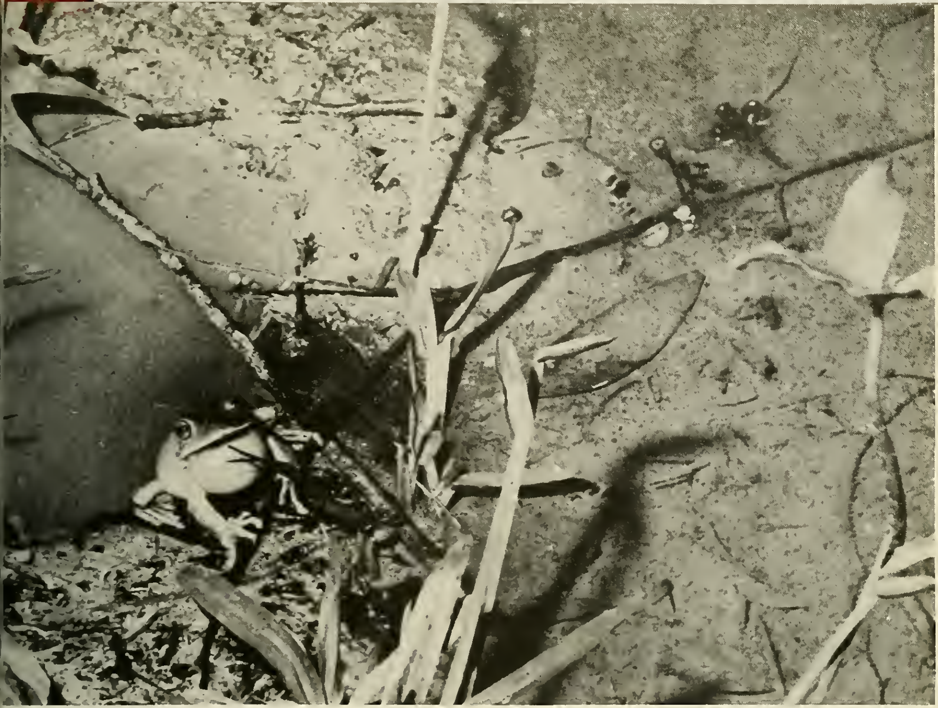
Raising rampart around edge of his nest, a male frog pushes moist earth into place. The female of the species does not help the male build the nest.

blacksmith, and illustrated the animal in a demure watercolor.

Hyla faber, a tree frog, builds nests for spawning and displays a complex pattern of nuptial behavior involving a rudimentary sense of territory and fighting among the males for nests. Its nests were first discovered in 1893 at Colonia Alpina in Teresópolis, Brazil, by the Swiss naturalists Emil and August Goeldi. They observed the frogs' nests by moonlight, but saw them only when empty or when they contained mated pairs of *Hyla faber*. Emil Goeldi published these observations, but he wrongly attributed the nest-building activities to the female, claiming that the male sat by passively.

An excellent opportunity to observe the activities of *Hyla faber* was afforded the author, her brother Professor Gualter A. Lutz, and their late assistant, Joaquim Venancio, at the *Açude da Solidão* (Pool of Solitude), situated in a clearing at the edge of the Tijuca forest, outside Rio de Janeiro. A brook forms the pool, which has been dammed at its lower end. The path round the pool has been planted with trees. The spot is protected against depredation and a colony of *Hyla faber* has become established beside the pool.

The nests, built at the edges or in shallows of pools, have raised walls. Perfect nests are rounded, about twelve inches in diameter, and are from two and four-fifths to three and three-fifths inches deep, with a rampart rising two to two and four-fifths inches above water. The male builds them by entering the water, sitting in a shallow place and circling to form a cavity, which he gradually deepens. He builds walls by pushing up clay



ISED ON RAMPART of his finished nesting pan, a male *yla faber* swells throat in song, *above*, to attract mates.

WAITING ON RIM OF NEST, male looks at two approaching females, *below*. He will eventually seize one as a partner.

and patting it on the rampart with his hands. Occasionally he goes under, brings up material on his snout, and adds it to the wall.

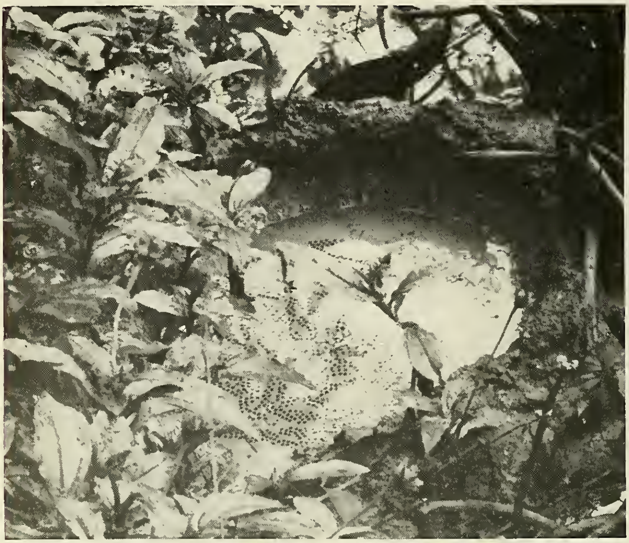
When the nest is finished, or sometimes even before, the male stops working and starts singing, from a position inside the nest, on the rampart, or even outside the nest. However, he is always near the nest. His call attracts females ready to spawn, who approach cautiously. They halt now and then in an odd position, sitting on their hind limbs and stretching out their arms. Finally a female enters the nest, swims up behind the male, and, eventually, lays a hand on his back. At first the male keeps calling, then suddenly he turns and seizes his prospective mate about her thorax.

FIGHTS between males were seen several times. They may occur in the nest or outside it. The fighters encircle each other's head and neck with their arms, placing their hands so as to be able to drive their sharp, rudimentary thumbs into the foe. Meanwhile, they may wrestle, using their long legs to try to push each other under while keeping their own nostrils above water. They may thrash round or lie still, with legs drawn up under their inflated bodies; or the stronger or more agile frog may mount his adversary and try to drown him.

Dr. Lutz, senior naturalist at the Museu Nacional in Brazil, observed *Hyla faber* in 1951 and in 1959. Her brother, of the University of Brazil, took the photographs for the article.

While fighting, the frogs may fall from the nest and continue the battle on shore or in the pond, or break off the combat. A fighting pair can be lifted, moved, and examined. One may see the skin round the rudimentary thumb pushed down to bare its curved point. A fighter may have both thumbs dug into his opponent. If one gently lifts the spur out, it is promptly thrust in again. After some handling, the frogs disengage and hop away.

The gravity of spur wounds depends on the parts injured. One dead male taken from the water showed a trickle of blood beside the eardrum. During amplexus, the sexual embrace, the female may be severely hurt by the male's thumbs pushed into her chest as he holds her forcibly. The male repeatedly presses his mate so hard that she is ducked. When coming up, she sometimes brings clay from below and pushes it onto the wall. Our studies indicate this is her one contribution to nest building.



SURFACE OF A NESTING PAN, *above*, is dotted with eggs morning after mating.

MATING IN NEST, *right*, a male grips a female tightly during sexual embrace.

Snowflakes on a slide, collected and preserved by the author.

YOUNG SCIENTIST

A study of the varieties and molecule structure of snowflakes

By Barbara Dymond

PERHAPS THE MOST COMMON of nature's beauties—the snowflake—is the least known. Taken for granted by most people, this delicately and intricately patterned crystal holds a great mystery that has baffled many meteorologists and other scientists. Although considerable research has been done on snowflakes by Ukichiro Nakaya of Japan, Vincent J. Schaefer of Schenectady, New York, and Wilson Alwyn Bentley of Jericho, Vermont, no one has as yet been able to come up with a suitable explanation as to how and why they form.

I have been working with snowflakes for a year and a half now, dating from the first time I saw some snowflakes preserved on a slide and decided to find out how I might go about doing this myself. The directions call for a one per cent solution made with a plastic resin that can be obtained commercially, and used with ethylene dichloride as solvent.

Here is the complete procedure for snowflake collection:

1. Make a one per cent solution by weight of the ethylene dichloride and the resin. *Be careful when using ethylene dichloride—it is highly inflammable and its fumes are very poisonous if inhaled.*

2. The equipment you will need is: microscope slides; solution; black cardboard; a fine, pointed paintbrush or an eye dropper; and a magnifying glass.

3. It is best if you keep all this equipment in the freezer so that when it does snow you will be prepared and able to collect snowflakes.

4. When snow falls, take equipment outside, preferably to a sheltered porch.

5. Catch snowflakes on the black cardboard. Then use a magnifying glass to determine which ones are the best.

6. Place a drop of *cold* resin solution on the cold microscope slide. For best results, the drop should be no larger in diameter than is the snowflake itself.

7. Pick up the selected flake carefully with the point of the brush (or eye dropper), which has been previously dipped into the resin solution. This wets it sufficiently to make the flake stick.

8. Deposit the flake *flat* on the drop of resin on the cold slide.

9. Allow the resin to harden. This will take three to five minutes.

10. *Do not breathe* on the flake or the slide, for this would melt the flake at once and ruin the specimen.

It is known that snowflakes form at very high altitudes in the clouds. The actual snowflake starts forming when water that is evaporated from the earth's surface travels to high altitudes and then cools and condenses at very low temperatures, forming a crystalline structure around a very small particle—a nucleus. This nucleus is about five hundred-thousandths of an inch in diameter. Its composition is in dispute. It could be gas, ions, salt, or dirt particles.

The snowflake grows as more water molecules are added to it from the surrounding atmosphere. Finally the flake becomes too heavy for the cloud that contains it. It drops into the lower reaches of the atmosphere, growing larger and heavier until it falls to earth.

The temperature of the air in which a snowflake grows varies, as do the pressure and humidity, but it is usually between 4°C. and –40°C. A low pressure with much humidity at a high temperature will produce large wet snowflakes that will tend to clump together as they fall. These clumps (or clusters) may be as large as two inches across. However, high pressure, very cold temperature, and very little humidity will produce tiny snowflakes that are usually in the form of hexagonal plates.

No matter what the conditions are under which snowflakes form, all have six sides and certain characteristics that make it possible for us to classify them The six main classifications are: hexagonal plates; hexagonal plates with extensions; stellar; ice needles; hexagonal columns; and capped hexagona columns. Each of these classification has certain characteristics making i easy to distinguish. Occasionally, snowflake may form with three, four, o five sides. The reason for this is unknown; it might be compared with th rare formation of a four-leaf clover.

Hexagonal plates are thin, six-side snowflakes made up of water molecule arranged in a lattice pattern. Some hav plain surfaces, while others have raise hollow designs that are symmetrica (both sides have an identical, co responding design).

Hexagonal plate extensions are th same plates, but with broad, simple arm that form in the last stages of the snow flakes' development. These snowflake usually have a simple, raised design.

Stellar snowflakes have six arms o rays that tend to give them a starlik

BARBARA DYMOND of Dalton, Pennsylvania, conducted her studies of snowflakes last year while still a junior at Benton Township High School. Her prize-winning work sent her to the National Science Fair in Indianapolis, and has made her the fourth young scientist to be presented in NATURAL HISTORY. Miss Dymond's paper is followed by a commentary written by JOSEPH M. CHAMBERLAIN, Chairman of the AMERICAN MUSEUM-HAYDEN PLANETARIUM.

appearance. They are found in many different forms—fern-leaved, dendritic, stellar with dendritic plates at the end of the arms, and simple stellar.

Ice needles are slender, hexagonal ice columns with long, sharp, jagged, and irregular points that extend from each end. They often fall during a snowstorm.

Hexagonal columns are similar tiny, six-sided prisms of transparent ice, but they are usually flat at both ends and have a long hollow extending from the ends toward the center. They are very light, and sometimes do not fall to the earth but remain aloft in the atmosphere.

Capped hexagonal columns have plates growing at each end and sometimes at the center. The plates all have their own designs and are seldom alike.

There are also other types of snowflakes that fall only under specific atmospheric conditions. Some of these are malformed, rimed and spatial crystals, powder snow, asymmetrical crystals, graupel, bullets, sleet, and hail.

The pattern a snowflake follows as it grows is determined by temperature, relative humidity, barometric pressure, altitude, the nuclear particle around which it forms, and the molecular structure. It is impossible to pinpoint the size and kind of snowflake to any one of these causes. The lattice pattern or structure of the snowflake is very important, but until now there has been no acceptable explanation of the molecular arrangement composing it.

To explain how snowflakes form, we must know what a snowflake is. A snowflake is a crystal of solid water having six sides, a symmetrical design, and a definite structure that is made up of polar water molecules.

What, then, is the polar water molecule and how does it affect the structure? The polar water molecule is a molecule of water that is formed when two atoms of hydrogen with an angle of 105° between them combine with an oxygen atom. The angle of 105° tends to make the electrical charges in the molecule unbalanced. Since the nucleus carries a positive charge and the electrons a negative charge, the side of the molecule on which the two hydrogen atoms are located is positively charged and the other, negatively charged. This creates a certain attraction for water molecules to other molecules having a charge (either water molecules or other polar molecules). When the temperature drops the molecular action decreases and the polar molecules become more attracted to each other. Since they are all polar in the same way, they form a pattern of attraction—that is, the molecules are attracted to each in a specific way—whereby a definite pattern is formed known as the molecular structure. Once a molecular structure is set up, the snowflake grows with ease by symmetrically adding more and more polar water molecules.

The molecular structure of the snowflake will be different from that of other compounds having polar molecules. One compound, however, does behave like and have a similar structure to snowflakes—this is iodoform, which forms hexagonal crystals at room temperature.

The pattern of attraction of the snowflake seems to be unique. The snowflake grows from a basic hexagon made of twelve polar water molecules that come together. It forms a hexagon because of the alternate combination of the polar water molecules that have their hydrogen atoms in each of two planes.

A minimum of two planes is necessary for the formation of any snow crystal and without planes made up of at least twelve molecules there would be no ice crystal. Additional planes can and are added as the snowflake grows.

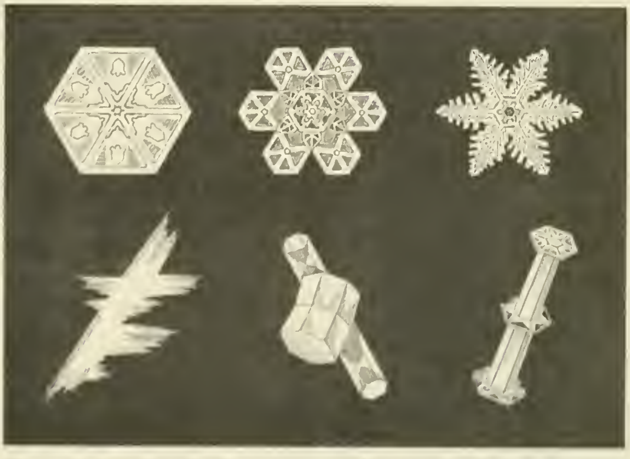
However, snowflakes are symmetrical. Hence, for each additional thickness, a plane must form that corresponds to the planes already existing. Additional fingers (crystals) may be added from the six sides of the basic structure, also symmetrically. This formation can take place only between 0° C. and 4° C., when the molecular motion is at a minimum.

The sizes and the variations of snowflakes are produced by symmetrical additions to the basic hexagonal structure. Arms may form on the existing arms by the addition of symmetrical hexagons.

Now, we know that stellar snowflakes have six arms and that each is identical, even though each had developed independently of others. Why, then, are they symmetrically identical? It is my opinion that the snowflake forms under very delicate conditions of equilibrium in which the very sensitive snowflake lattice is able to feel vibrations caused when new polar molecules join the structure. Their presence is felt through these vibrations, which are carried through the snowflake. Other molecules are attracted or repelled according to vibrational rates in parts of the snowflake.

The snow crystal, you will note, is flat and hexagonally shaped, while ice needles are long hexagons. After my work with snowflakes, I feel that there is a definite difference between snow and ice crystals. There is most probably a difference in the molecular structure of the two, and the stellar snowflake should be classified as a snow crystal, while ice needles should be classified as ice crystals. This would apply also to many of the snowflake cousins, some of which are frost, windowpane frost, hoarfrost, rime, glaze, sleet, and hail.

I would like very much to be able to prove my theory for the structure and formation of snowflakes, but it is impossible to do so because there is no equip-



SIX MAIN TYPES of snowflakes are: at top, hexagonal plates, plates with extensions, stellar; at bottom, ice needles, hexagonal columns, and capped hexagonal columns.

ATTRACT MORE BIRDS, MORE OFTEN

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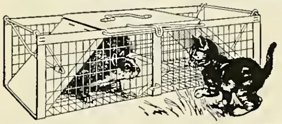

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ment available for detecting the position of the hydrogen atoms in either a snowflake or ice crystal. The fact that it has been possible to determine the angle of 105° that is formed by the two hydrogen atoms in the polar water molecule by the use of X-ray diffraction has been construed by many authors and scientists to be applicable to ice and snow. It could be theorized that the angle formed by hydrogen atoms in the water molecule could change in the solid formation of ice and snow. I have assumed in my theory that this does not occur, and that the angle of 105° between the hydrogen atoms also exists in the crystal. To prove the crystal structure of ice and snow by X-ray diffraction, as has been done with water, would require X-ray equipment and a cold chamber capable of operating at a temperature far below 0°C.

COMMENTARY

There is still much to be learned about the way in which a snowflake forms initially and about the processes by which it becomes a combination of crystals that fall to earth. Increasingly ambitious studies have accumulated information that helps to classify these latter combinations. Conclusions about the former event are far fewer.

Meteorology—as compared to most of the other physical sciences—is not favored with a large number of researchers, and the task of forecasting, in itself, limits the amount of time available for basic research. The impression should not be left, however, that no concern exists for uncovering fundamental concepts. A small but capable and productive group of scholars have been working on many aspects of the science. With respect to research on snow crystals, the names of Kepler, Descartes, and Hooke are prominent in early efforts, and more recently the vast collection of over three thousand photomicrographs of snow crystals, described by Bentley and Humphries, is a recognized scientific masterpiece. Dobrowolski published a comprehensive study of snow crystals in 1923. Schaefer, Langmuir, Nakaya, and others continued the investigations.

Miss Dymond has recognized these facts. She has approached the study of snowflake structure in the normal routine of a seasoned investigator: by acquiring specimens in an acceptable manner, by determining as much as possible from their appearance, by reviewing the available literature for reports of the experience of others, and by extrapolating from associated studies of crystal and molecular structure.

The process of snow formation is usually classified as taking place in two distinct stages. The first accounts for the "germ," which is first formed in the upper atmosphere as a result of sublimation of water vapor on a nucleus, or by the spontaneous emergence of the germ as a supercooled droplet. The second is the continuing growth and modification of the germ following its original formation, resulting in the snow crystal proper. The tiny germ, with dimensions of a few hundredths of a millimeter, often possesses observable varieties of crystal shape, but it is the mature snow crystal, grown to a size of several millimeters, that is seen on the ground.

The mature snow crystal has been classified in this student work. The many photographs acquired show patience and craftsman-like technique, and support the descriptive material nicely.

The very interesting discussion of the polar water molecule and the part that it plays in the formation of the crystal germ is an attempt to account for the original development of the germ. It is commendable that a fledgling investigator should be willing to stride smartly into an area of theory where experienced scientists have trod but lightly. It is true that there is no universally accepted explanation of the molecular arrangement that must account for the formation of the crystal germ. There have been, however, a number of studies in which the process has been duplicated artificially. For example, the experiments on cloud modification, carried out by Langmuir and Schaefer, were successful attempts to transform supercooled cloud droplets into germs. As a result, some characteristics of the germs and the conditions under which they form are rather well established.

Miss Dymond is to be commended no only for a fine job of accumulating thes fragile specimens and evaluating th field, but also for a well-reasoned, original excursion into basic theory.

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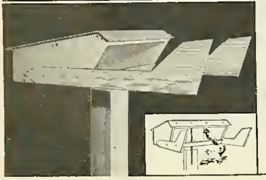

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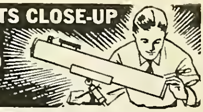

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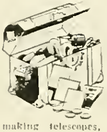

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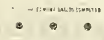

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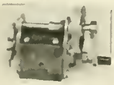

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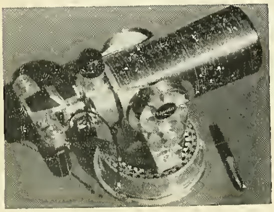

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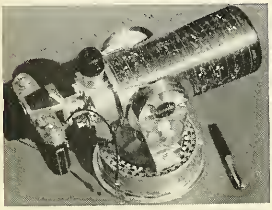

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NATURE AND THE CAMERA *David Linton*

COVER: Everyone knows that frogs can and do jump for a variety of reason Yet, surprisingly, much of the scientific data on *how* frogs jump are still eith controversial or out of date. Ostensibly, the cover picture is simply a remarkab view of a gape-mouthed bullfrog that has successfully captured some foo Actually, it is the result of a happy collaboration—and intensive work—by Merv F. Roberts, engineer and photographer, and Dr. Carl Gans, engineer ar zoologist. Their research was designed to explore some of the little-known detai of the function and control of the bullfrog's "propulsion mechanism"—its metho of aiming at and actually capturing the prey. The discussion of its unusu abilities and more of Mr. Roberts' extraordinary photographs begin on page 2

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MUSEUM MEMO

By John O'Reilly

Thanks to the thoughtfulness of the late Miss Augusta S. Kalbfleisch, a ninety-four-acre estate on Long Is- nd has become the Museum's scientific backyard. Lo- ted near Huntington. only forty-seven miles from Man- ttan. the Kalbfleisch Field Research Station is already zzing with various scientific departments' projects.

This latest addition to the Museum's list of field stations quite unlike any of the others. both in its physical aspects d in the scientific purposes involved. At the Southwest- n Research Station in Arizona. for example. scientists am five life zones ranging from desert floor to mountain p. At the Lerner Marine Laboratory, at Bimini. Baha- as, they have the whole wide ocean to study. At the Arch- ld Biological Station. the rich flora and fauna of Florida e at their disposal. The scientists working at those sta- ns may move far afield. but here on Long Island the rk is all done right on the property.

Here, long-term projects—involving carefully managed bitats—are already under way. ne advantage is that this back- rd laboratory is within easy com- ting distance. A researcher can t up a project with the knowledge at it is handy and permanent. me even pass their weekends rking there. It is a unique estab- hment and this is how it came out: Miss Kalbfleisch—a woman th a great love for wildlife and r birds in particular—had main- ned her estate as a bird sanctu- y for almost thirty years. Upon r death in 1956, she left the prop- ty and a sizable endowment to e Museum. Her will expressed the earnest desire that the ea be used as a bird sanctuary and field station. The perty includes a main house, a caretaker's cottage, a rn, and other outbuildings. Dr. Wesley E. Lanyon, of e Department of Ornithology, is Resident Director.

Some things had to be done right away. The first was to t a six-foot, chain link fence around the entire prop- ty, to safeguard outdoor scientific apparatus, to prevent lation by domestic animals, and to keep out hunters. e next step was to prepare a description of the vegeta- n, along with a map and a land-use history. The latter ludes such information as how long various fields have en fallow, the logging history of the woodlands, and the es of ornamental plantings. Without a management program, the property would gradually return to oak-hickory woodland. The aim, however, is to preserve the different types of cover, while making certain changes. Some weed fields are being sprayed with chemicals to eliminate woody growth; some fields will be burned annually, with the local fire department's aid. In some selected second-growth woodland areas, certain large trees will be killed and left standing, while other woodland areas will be ground-burned in order to alter the forest litter.

With the management program under way, members of the Museum staff and students began taking a basic inventory of the flora and fauna. Dr. Richard G. Van Gelder went to work on the mammals. Dr. Jack McCormick undertook vegetation studies, and Dr. Richard G. Zweifel made an inventory of the reptiles and amphibians. Apart from these surveys, various special projects already are under way. In two years, Dr. Lanyon has banded almost four thousand birds. Dr. Zweifel has marked more than a hundred Fowler's toads and Dr. Van Gelder is studying fluctuating mammal populations. Although it is the youngest of the field stations, this backyard laboratory is a busy place. It is necessarily closed to the public because visitors would interfere with the work in progress. Throughout the area are objects strange to any backyard. Metal posts mark the corners of squares in a grid system covering the entire property. Laboratories house the paraphernalia of modern biology. Dr. Kenneth L. Franklin, Associate Astronomer of the Museum's Hayden-Planetarium, has set up apparatus for his studies of radiation from Jupiter. Native animals from birds to toads, wear bands or colored markings.

Says Dr. Lanyon: "the property is operating as a field station where our biologists can carry on long-term projects. There has long been a need for such a station within commuting distance of the city. Research is our primary purpose, but many of the things we are doing will provide greater sanctuary for the area's wildlife."

An old popular song says, "You'll see your castle in Spain, through your window pane; back in your own backyard.'* With this fine beginning on Long Island, we don't hesitate to look into the future and see the Museum's backyard laboratory producing all sorts of scientific treasures.

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Reviews

Sahara survey vs. a study in dept

Tribes of the Sahara, by Lloyd Cabot Briggs. *Harvard University Press, $6.00; 295 pp.* Beyond the Mountains of the Moon, by Edward H. Winter. *University of Illinois Press, $5.50; 276 pp.*

"The proper study of mankind," Alexander Pope wrote, "is Man," and this is a good argument for the validity of anthropology as a discipline. But sometimes one wonders if the anthropologist is doing the job. There is probably no more and no less disagreement among anthropologists themselves than among any other group of scientists. Yet the anthropologists' disagreements are over such important and vital things as objective and method, not facts alone.

The wide field of anthropology is now legitimately divided into three specialist groups: one group looks at man as a physical entity; another, man as a historical entity; and the third, man as a social entity. In this last group, the conflict of ideals is at times bewildering. The two books under review illustrate this conflict, for they are quite as different as the parts of Africa they concern: the Desert Sahara and the lush forests and foothills of the Ruwenzori Mountains. Each book sets out with a different objective: each, to a varying extent, succeeds. Their relative importance, then, depends on the value of the objective. Dr. Briggs sets out to give a general survey of the Sahara's population, and that is what we get. Dr. Winter, on the other hand, sets out to enter the lives of the Bwamba people and to see the world as they see it. As a result, the reader understands one situation well instead of several hundred poorly. Reaching the end of *Beyond the Mountains of the Moon,* he feels that he has indeed gone far "beyond"—that he has actually entered the lives of the people and begun to understand not only how they live, but how they think and feel. And, above all, he has the impression that the author is an anthropologist who understands Pope's dictum.

This view may sound jaundiced on the one hand and warmly prejudiced on the other, but there are many things about *Tribes of the Sahara* to turn one as yellow as the sands. My initial reaction was favorable: having been in the Sahara myself and having once traveled right across it, I responded gladly to the opening lines of the preface: "There has been more balderdash written and repeated about the tribes of the Sahara than about almost any other peoples in the world." The publisher calls Dr. Briggs' research a "field and library work." Yet, to judge from the book, the author might as well never have set foot in the Desert. He often generalizes—with the excuse that no information is available—despite the field opportunities that were at his disposal. For example, he deplores the lack of data on a certain people of considerable interest, a community of blacksmiths living in the Ahaggar. No measurements, no blood analysis of a single one of them, he complains, no description of their social organization or even their kinship terminology, and not a dozen photographs of their faces are available to students. "Why?" he asks. "Simply because the Tuareg are spectacularly romantic whereas the smiths are not." Then why, one feels entitled to ask, does the author, himself, devote a complete chapter to the Tuareg, instead of spending some of his field time with the smiths? He was evidently in their neighborhood, for he publishes a photograph of the wife of a smith. Why not one of the smith himself?

Throughout this book, one feels exasperated at the fact that here is an intelligent man, a trained observer with an acute eye for detail, one who has traveled extensively in the Sahara, and yet who gives us agonizing details of the terminology used for different types of camel and takes pages to excuse the alleged treachery of the desert nomads in semipsychological terms that amount to no more than a description of the common instinct for self preservation.

Dr. Briggs raises a topic, then fails to follow through: for instance, he talks of inhabitants of the walled cities of Mzab and one becomes intensely curious about these people, about how they live and think. We are told in detail what they wear, and learn that they average about 5'4" in height. At last, after several pages, we read: "They are set apart from all other Saharan peoples"—and we hope for something significant—"by the fact that their arms are remarkably long although their legs are relatively short. They have narrow shoulders but rather broad hips, and they often become paunchy in middle age." Even if this book were designed for aspiring physical anthropologists, which it is not, this would be pretty meaningless. For the general reader, it is useless.

Similarly, one learns of the "romantic" Tuareg that they possess 12,000 camels, 2,000 sheep, 20,000 goats, 5,000 donkeys, and 300 head of cattle. It
all the author says of their religions
that "The Tuareg in general have
embraced Islam; but for the most pa
they are lukewarm and superficial co
verts." The book is studded with su
contrasts of nearly irrelevant detail a
meaningless generalization.

It is only fair to say that Dr. Briggs
set out "to make readily available
over-all summary of what is kno
about the subject." This, in itself, is
formidable task, as the literature of t
Sahara is scattered and unreliab
Dr. Briggs did an excellent job of s
ing, and has added some fresh inform
tion, but anyone seriously interested
still going to have to go to the origi
sources, while the general reader, ho
ing to learn what the tribes are li
today, is going to be disappointed.

Of a totally different character, B
yond the Mountains of the Mo
succeeds exactly where *Tribes of t*
Sahara fails. The task Dr. Winter
himself was not an easy one. It is c
that few anthropologists, unfortunate
choose to undertake. Instead of conf
ing himself to a vague, over-all surv
or even an objective analysis of soc
structure, the author penetrates to t
heart of Amba institutions by inve
gating the attitudes and feelings of t
people themselves.

Taking four individuals whom
knows, he has persuaded them to t
their life histories in their own wor
During the course of their autobiog
phies—which form the bulk of the book
one gets to know these four people
timately. So intimately, in fact, that t
reader may sometimes be shocked, f
in Dr. Winter's words, "When one fi
enters [the Amba] universe, it is
though one has entered through t
looking glass." Not only do the situ
tions that confront the Amba diff
from the situations that confront us, b
they look at their situations in a total
different way. But through knowi
these four living human beings, unde
standing their problems and seeing h
they resolve them, the reader not on
sees the Amba world as the Amba the
selves see it; he also comes to a mu
broader understanding of tribal life
Africa than the author claims to gi

Dr. Winter opens with an introducto
chapter describing the country in whi
the Amba live, their immediate histo
their present economy, and their re
tionship with neighboring tribes. I

By Colin Turnbull

n anthropologist, Mr. Turnbull is
e Assistant Curator of African Eth-
ology at The American Museum.

A street scene in city of Ghardaia, from *Tribes of the Sahara.*

ws how far and how little the British iinistration has affected their lives outlines the beliefs and customs of people, particularly those relating marriage and to witchcraft. These be the main topics discussed by the r autobiographers.

young man, Mpuga, is the central racter and the first to tell his story— ory of many loves and many wives. narration is followed by that of two nis wives, and finally a relative who Amba terms — is a brother to uga, but would be his step-father-in- in our terms. Then come excerpts n a diary Mpuga kept while Dr. Win- was conducting his research, so that can compare his attitude to the past his feelings about the present. Winter ends with a chapter that ws together the four stories.

ach life history has its own special racter, but each also has its similari- All four begin with minute details cerning birth and the events leading irth, revealing an intense preoccu- on with circumstances that would rivial to us, but which take on hid- significance in the world of the ba and may be considered as the su- atural cause of later misfortunes. each story is mainly concerned the problems of marital life.

Mpuga, we meet at once a fasci- ng combination of the old world of Amba and the new. For Mpuga is, ng other things, a very Christian po- nist who has had, by his own reck- g, a total of some thirty-six wives. dilemma is one that has considera- bearing on the manifold problems of can people today. They are passing one world to another, abandoning standards and values for new.

puga became a Christian for sev- reasons, and we may guess that his ons are shared by many others. He an ambitious boy who knew that to on in this new world he had to be to read and write. For him, Chris- ity was co-terminous with literacy, so he became a Christian. Also, it necessary for him to become a stian if he was to be respected in community. For Mpuga, then, the was both a means to education and gn of status.

t Mpuga also tried hard to be a good Christian. He met and married a girl, Lubangi, whose story is the second in the book. She was also Christian and insisted on a Christian wedding, which meant that Mpuga had to get rid of his other wives. He did so, and as the story unfolds we begin to see the conflict; for also necessary to status, in his community, is the possession of many wives. Eventually he solves the conflict unsatisfactorily by taking as many other wives as he wants, but saying he has only one Christian wife.

In Lubangi's story we see the woman's point of view. She is annoyed with her husband for deceiving her and reverting to polygyny, yet she is sufficiently traditional to accept the situation and even to help cook the marriage meals for her co-wives as they come, one by one. We learn how she likes some and dislikes others. She is not nearly as worried by the problem as her husband, for after all she is still a good Christian —she has only one husband. But she has other problems in common with both the menfolk and the women, and the fear of witchcraft is one of them. In all the accounts we feel this dread constantly behind every little act in the lives of the narrators.

In our world, witchcraft is something irrational, mere superstition. But, for the Amba, witchcraft is essentially practical: it is a means by which they come to terms with the unknown, by which they rationalize those things for which they can see no logical sequence of cause and effect. In the belief that the natural order of events is good, anything that is not good is unnatural and requires explanation. The failure of crops, sickness, and death itself, are all considered unnatural.

We see a lot of this in Dr. Winter's account. We see how a man fears his neighbors more than anyone else; so much so that, if he falls ill, he immedi-

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Amban pagan ceremony, from *Beyond the Mountains of the M n.*

ately suspects them as being the cause, and removes himself as far as he can. Mpuga blames most of his wife trouble on witchcraft and, in the end, is himself accused of being a witch. Another man, who denies the bond of blood-brotherhood, is accused of this crime together with the curse that, if the charge is true, his stomach will swell. Two months later, his stomach swells—and bursts open at death. We see events such as these occurring as part of the ordinary everyday life of the Amba. Even the Christian wife, Lubangi, was not free of a preoccupation with witchcraft.

Kihara—one of whose wives is the mother of one of Mpuga's wives, but who in his own right is a distant cousin to Mpuga—tells his story too. Kihara is the traditionalist of the group. His father was an important headman, unscrupulous and severe—qualities that had made him useful to the then newly arrived administration. Kihara inherits his father's traits, but the situation has changed, and the administration can no longer turn a blind eye to such high-handed methods, however helpful and effective they might have been in the past. Unlike his father, Kihara is not regarded with favor. He is also a pagan, proud of his old traditions and staunch in his refusal to betray them. This means that he is still illiterate, and consequently has no social status. Kihara would have liked to work for the government, even as a policeman, but his way is blocked by his own rejection of the values of the new order.

It might be said that Winter succeeds where Briggs fails because he confines himself to so limited a subject, while Briggs had a much larger and more diverse field to cover. The point remains that, whereas Briggs rep its what has been said before—albeit a more concise manner, and often th additional information—his book le es us feeling that the tribes of the Sal ra are as remote as ever. Winter, on he other hand, not only enables us to nderstand the small, relatively insig ficant tribe of Amba, but also sets u an example, putting us through an ex rience that should—if we are willin to learn by it—make it possible for u to look more intelligently at the ways. eliefs, and thoughts of any people di rent from ourselves. Anthropologists e, after all, dealing with human be gs and human societies, not mere statis s. Winter is every inch the scientist, ut he is also a human, and this book for ie general public is anthropology at ts best precisely because of this qua y.

BIRDS OF THE WEST INDIES, by Ja es Bond. *Houghton Mifflin, $6.00; 256 p.*

VISITORS to the West Indies and a hamas have been complaining or some years that no field guide to ie birds of these islands was available. ie present book will fill this need adm ably. It is authoritative, very well il strated, and represents the fruit of l g experience gained by James Bond l h in the field and in the preparatio of two earlier books on the birds of tl e islands. These works are out of p t, and the one now offered—while es tially similar to his successful *F d Guide to Birds of the West Indies* p lished in 1947—shows improvemen n the text, and, especially, the illustrati s.

The new book retains most of the e drawings made by Earl Poole for e earlier *Field Guide* and supplies ei t new color plates by Don R. Eckelbe y. These are well drawn and reprodu l, illustrate 66 species selected for r interest or beauty—among them, the hummingbirds that breed in Bahamas and Antilles proper. The describes 429 species, including, of rse, all the breeding birds, which ber nearly 300. The voice, habitat, nidification of these are mentioned. additional species consist of the ilar winter visitors or migrants and st of 53 vagrants is supplied also.

CHARLES VAURIE
THE AMERICAN MUSEUM

: KIRTLAND'S WARBLER, by Harold field. *Cranbrook Institute of Sci-*, *$6.00; 242 pp., illus.*

THE wood warblers are the favorites of American bird watchers. The ted States has 52 species of these rful migrants. Two of them, the land's — subject of this book — and Bachman's, are excessively rare. former warbler nests only in a lim- area in the jack pine barrens of hern Michigan and winters only in Bahama Islands. Of late, it seems to become even rarer and has not been on its wintering grounds or migra- routes in years. Exacting in its re- ements. Kirtland's warblers will only on extensive burned areas re the new-grown pines are no more ss than ten to fifteen feet tall. The ies is further threatened by an ap- nt increase in the cowbird, a nest site that destroys many warbler eggs leaves its voracious young to crowd ny young warblers that may succeed atching in the invaded nest.

ayfield, who has visited these war- s' nesting grounds year after year, in the company of his friend the Professor Van Tyne has written a iled, well-reasoned, and—insofar as nesting season is concerned—complete account of this unique warbler. Every serious student of American birds will wish to have it.

DEAN AMADON
THE AMERICAN MUSEUM

CURIOUS NATURALISTS, by Niko Tinbergen. *Basic Books, $5.00; 280 pp., illus.*

NIKO TINBERGEN, the eminent naturalist and student of animal behavior, has written a charming book. It will stimulate the incipient naturalist to go out and look; it will encourage the experienced naturalist to extend his observations and to test his theories with field experiments, so well outlined by Tinbergen. Inexperienced and experienced observers alike will find more meaning in the relationship of insects and birds among their own species, among other species, and with their physical and biological environment.

The studies cited in the book reflect the history of Tinbergen's development as a naturalist-scientist, starting with his first experiences as a graduate student in Holland. He covers a trip to the Arctic, his observations on snow buntings, gulls, eider ducks, kittiwakes, bees, sand wasps, moths, and his experiments on camouflage and mimicry. Among his more fascinating researches — and, incidentally, his first — are descriptions of the "Bee Hunters of Hulshorst," a group of digger wasps who eat honey bees and provide their young with ample supplies of bees while the young develop in burrows. His experiments, performed in the field over a long period of time, show how a naturalist determines which cues in the environment are important to the wasp's recognition of the honey bee and of his own home territory. Exciting, too, is his story of the natural history of the hobbies, great birds of prey with remarkable powers of flight. But when Tinbergen relates his other bird studies, some of his former anthropomorphism creeps into the pages. He tended, in an earlier book, *The Herring Gull's World*, to humanize relationships between his birds, using words such as love, marriage, and flirting to describe courtship behavior in the gulls. He does not completely succumb to this temptation here, but occasionally he does backslide into the world of humanistic birds.

Many of the general descriptions of terrain and climate in the Arctic, Holland, and England are colorful and evocative; they reflect Tinbergen's great love of animals and the out of doors. Unfortunately, his style is uneven, his tenses jump from past to present, and sometimes the trend of thought disappears completely and a new one, unannounced, appears in its place. Moreover, his scientific interpretations are single-minded—suggestions of other theories would make the book more useful to the scientist, and also inform the amateur that certain activities may have a number of different, and often contradictory, interpretations.

EVELYN SHAW
THE AMERICAN MUSEUM

ERRATUM

The picture caption for an illustration reprinted from J. D. Carthy's *The World of Feeling* in the December, 1960, issue of NATURAL HISTORY was completely in error. The caption attributed to the daylight blindness of the retinal rods a phenomenon that, instead, is caused by the blind spot (where the optic nerve leaves the eyeball) in the human eye. The editors regret this error and wish to emphasize that the mistake is not the responsibility of either the author or the reviewer.

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Great Horns and High Alps

Saved from extinction, ibexes now abound

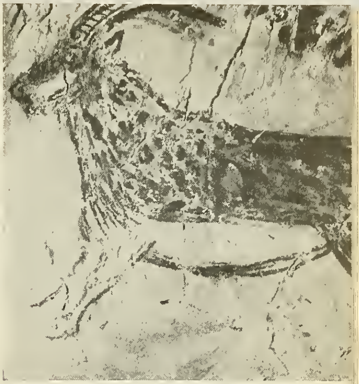
By Dieter Burckhardt

As early as the sixteenth and seventeenth centuries, the ibex—proud heraldic animal of many families and communities in the eastern part of the Swiss Alps—had begun to disappear. In 1809, the last known ibex was shot by a hunter in the canton of Wallis in the Western Alps. With this event, Switzerland seemed to have lost forever a characteristic representative of the Alpine fauna. The situation was not much better in other Alpine countries. In the Austrian Alps and in French Alpine regions, the ibex was decimated until the fate of the species depended upon a few animals surviving in the Val d'Aosta, in the Graian Alps of Italy. At the last moment, in 1827, the government of Piedmont proclaimed strict protective measures for these remaining representatives of a species that had inhabited the entire Central European Alpine Zone at least from late Paleolithic times. In 1856, the Italian King Vittorio Emmanuele II, popularly known as *re cacciatore* (the hunter king), became the protector of these last animals. The Gran Paradiso of Aosta was made a royal hunting preserve where 150 gamekeepers saw that the remaining ibexes could breed undisturbed. The king's successors also protected the rare animals. In 1921, Vittorio Emmanuele III presented the preserve in the Val d'Aosta to the Italian people, founding today's "Parco Nazionale del Gran Paradiso." The ibex had been saved. Even though World War II and the postwar period had disastrous consequences for the ibexes in the Gran Paradiso—they decreased from more than 4,000 to less than 400—the colony there, restored to 5,000 animals today, is Europe's largest, and is the only one preserved under natural conditions. The photographs by Fritz Siedel that illustrate this article were taken in that preserve.

Imposing ibex, called *Steinbock* in German, was once faced with oblivion.

As early as the nineteenth century, attempts were made in Switzerland and elsewhere to start ibex colonies. These efforts failed, however, because it was difficult then to obtain pure-blooded ibexes. Because it was easy to interbreed ibexes and domestic goats, whose offspring proved fertile, ibex-goat hybrids were used in the colonizing experiments. Spiteful critics of the experiments asserted that the hybrids showed the bad traits of both parent species. The fact remains that these efforts were unsuccessful. All these failures, however, did not discourage the ibexes' friends. At the end of June, 1906, a group of Swiss protectors of nature obtained three four-week-old ibex kids from the Gran Paradiso. In succeeding years, more ibexes were procured from the Val d'Aosta. On June 15, 1909, the females obtained in 1906 had their first young, and by 1911, this small breeding colony numbered eleven head. The time had arrived to put out pure-blooded ibexes in the Swiss Alps.

May 8, 1911, has a special significance in the history of the Swiss League for the Protection of Nature. On that day, a strange procession of nine porters, three gamekeepers, and several noted members of the League and of various governmental authorities, moved into the area of the "Gray Horns" in the Alps of Saint Gallen. Five boxes—weighing from 88 to 187 pounds—were carried up the steep slopes. In them were a three-year-old male ibex, two two-year-old females, and one male and female, both one year old. Finally the group reached its destination and the boxes were opened. Haltingly, the animals took their first steps into the new-found freedom of the Alps.

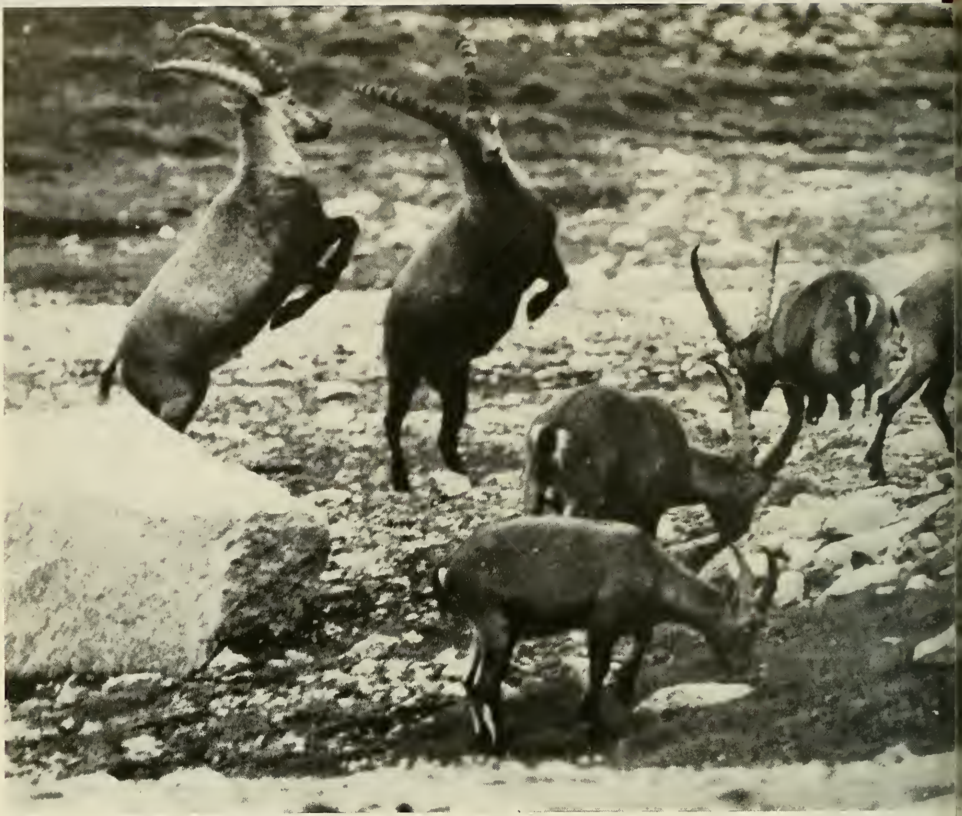


Upper Paleolithic painting of ibex is on wall of a cave at Niaux, France.

With touching care, the gamekeepers watched over the fate of the rare animals. Unfortunately, the eldest male and one two-year-old female were unable to adjust to a natural life. They had to be recaptured and taken back to the zoo where they had been raised. Despite these setbacks, the way had been paved for the resettlement of ibexes in the Alps.

Another breeding station for pure-blooded ibexes was established near Interlaken, in the canton of Berne, in 1915. Today, three more breeding stations are in existence. However, the importance of these stations has declined considerably. For several years, wild ibexes—taken from the flourishing colonies at Piz Albris near Pontresina, at the Augstmatterhorn above the Lake of Brienz, in the Bernese Oberland, and at Mont Pleureur in the canton of Wallis—have been used to found new colonies.

Now, fifty years after the first resettling experiment in the canton of Saint Gallen, all Swiss Alpine cantons possess ibex colonies—with a total of 2,000 animals. The preservation of this remarkable species, which was seriously threatened by imminent extermination a mere 100 years ago, has now been definitely secured.



Rising on hind legs, two male ibexes assume a fighting stance similar to that of male goats. A battle will usually start with a crossing of horns, followed by pushing. After rising, as shown, they come together with thunderous noise.

How could this threat to ibex survival have arisen in the first place? Until recently, man alone was blamed. In the late Middle Ages, indeed, the ibex was regarded as a "roaming pharmacy." Every part of its body—even its excrement—was regarded as having medicinal value. Drugs derived from the ibex were much in demand and brought high prices. To play such a role in folk medicine, however, a species must be rare. Therefore, I believe the medicinal effects ascribed to the ibex—and consequent hunting pressure—were only one of the factors that nearly led to the species' extermination. The ibex was apparently not as widely distributed in the Central European Alpine Zone as the chamois, for instance. Experiences of the past fifty years have shown that the ibex is far more demanding in habitat than is the chamois. Thanks to a generous grant made by the Swiss Endowment for Alpine Research, a thorough investigation of the ibex life cycle is to begin in 1961. From observations to date, however, we may draw the preliminary conclusion that ibexes need much more sun than the chamois and depend, especially in winter, upon steep slopes inclined to the south. Wherever these factors were taken into consideration, resettlement experiments were successful.

The most famous example of such an experiment is the colony in the Swiss National Park in the Lower Engadine. In this area, which was once inhabited by ibexes, seven animals were set free in 1920. The Val Cluozza, which was chosen for the resettlement, is characterized by a large stock of chamois; but slopes inclined to the south are lacking in this valley. For this reason, four of the seven animals set free there left the area in 1921. Regrettably, they went to the neighboring Italian Val Livigno, which was then known for its poachers. Two ibexes, both males, were killed. The remaining two, females, migrated southward and reached Swiss territory near Pontresina after traveling about eighteen miles. At Piz Albris they found an area that could not be better for ibexes. Fortunately, the two females were recognized as ibexes by the local gamekeeper, Mr. A. Rauch. Thanks to his persistence, two males—sent from a zoo in 1922—joined the females. Piz Albris is now the largest Swiss ibex colony. More than 250 animals have been captured at Piz Albris during the past five years, to be set free in other areas.

The example of the ibex demonstrates that the preservation and resettlement of animals as large as these in a zone as densely populated and highly industrialized as Central Europe is definitely possible, and can be successful. The story is exciting;

ndeed. It is, however, even more fascinating to observe these animals in the reedom of nature. The environment tself—Alpine meadows strewn with lowers, snow-covered majestic mounains, and awe-inspiring precipices—s sure to evoke a unique mood in the tudent of nature.

Looking for ibexes, one must oberve slopes and ridges carefully. Even though the animals should be ather conspicuous because of their mighty horns, one is often surprised at how well the ibex, with its fallow, ellowish-gray color, blends into its urroundings. Suddenly one discovers the silhouette of an old male ibex on the horizon. The animal stands motionless against the bright blue ky. Like two Turkish sabers, his horns—nearly a yard long and decoated with large ridges—soar into the ir. One may discover five, six, even a dozen of the heavy animals as they lie partly concealed among the steep ocks. Some doze, others chew cud; till others seem content simply to let he sun warm their thick fur.

Any sense of time seems alien to hese mighty beasts. One could spend hours watching them. Typical posures of the ibex include stretching all our limbs; resting the chin on a conenient prop; or holding the head up o the sun can shine on the entire neck. Or the heavy head may be supported by resting a massive horn on a rock. An old male may rise slowly, raise his head, and use his long horns to comb his two flanks simultaneously. Then he may scratch himself with the tip of one horn. It is amazing to see how many uses the male has for his horns: support, "comb," scratching instrument, or weapon for beating, pushing, and stabbing.

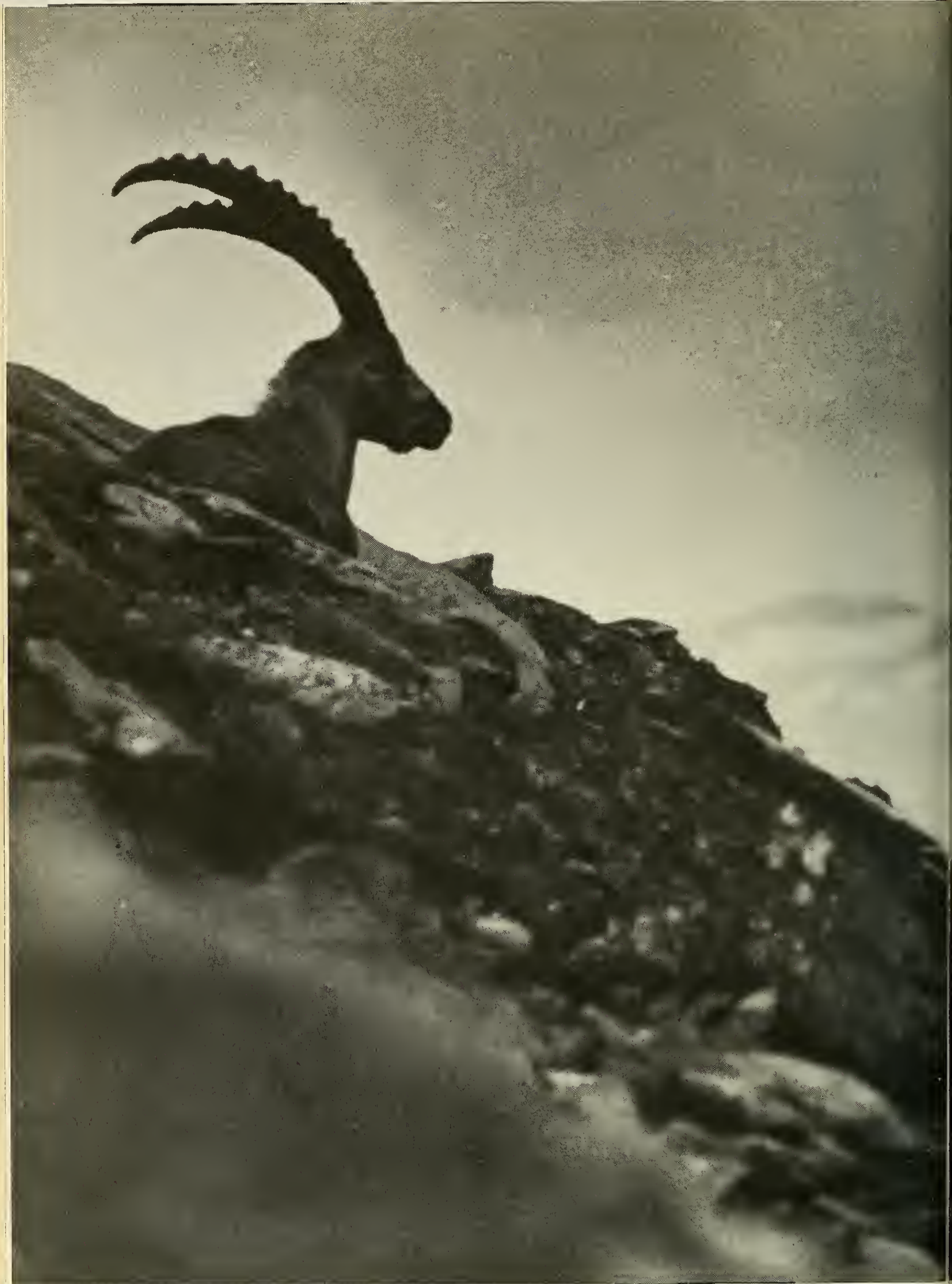
When the herd comes to life, the plump animals jump to their feet with unexpected agility and present a unique, breathtaking spectacle: in mighty bounds they take flight over steep rocks. Dizziness seems foreign to them. It is inconceivable that their hoofs can find a hold. Rocks loosened by their passage rumble down the mountains, sounding like thunder and arousing still other, unnoticed ibexes. Their flight slows. The animals disappear into a ravine, then emerge on the other side at some towering rock. Now they reach a strip of vegetation that broadens gradually into a meadow covered with lush herbs and grasses. Here the band of fleet-footed ibexes begins to graze.

So far we have talked only about males and it is no accident that only males are shown in the photographs on these pages. Except for the rutting season, which occurs (in areas known to me) from the end of December to mid-January, the old males live isolated from females and the young. They spend the summer in groups of various size, high among mountain crests and ridges. The females and their young spend the summer at somewhat lower altitudes. Immature male and female ibexes remain in the same area as the adult females, but stay in separate herds. Exceptions to this rule are frequent, however.

The strong, almost plump, old males are imposing because of their size and mighty horns. The females appear charming because of their delicate build. Compared to the males, which weigh up to 220 pounds the females weigh a mere 88 pounds normally. Their short, slender, pointed horns are seldom longer than a foot. They also lack the small beard that adorns the old males' chins.

THE new-born young are delightful: like little goat kids, they are full of exuberance and mischief. One is always afraid they may break their thin legs when playing. While their mothers chew cud, the kids chase each other. A small rock may be the goal of their leaps: one will hardly reach the top before the next comes and tries to push him down. They are particularly fond of this game if one of

ATURE MALES live in herds apart from females and young xcept during the rutting season. Altitude also separates them, since males spend the summer months in areas higher than those chosen by their less robust mates and offspring.



Two MALE IBEXES lie on high ledge in the Gran Paradiso, a national park in the Italian Alps. Profile of the ibex at left shows saber-like sweep of its horns, small bear and strong neck. Ibexes usually favor slopes facing soutl

Dr. Burckhardt, Secretary of the Swiss League for the Protection of Nature, also edits its Bulletin. He has devoted much time to observing animals in the Swiss National Park.

the mothers plays the role of the rock. Showing no signs of being disturbed. the female allows her young to jump onto her back repeatedly and to climb all over her. Only her head is off limits; but this is the most desirable goal of the young ibexes' climbing tour. Shaking her head, the mother finally chases her young tormentors away.

After a while, the young ones get tired. One after another, they lie down. pressing close to the mother. It is interesting to note that the young ibex always lies behind the mother on her higher side of the slope. One reason may well be the danger of attack by their only large enemy, the golden eagle, which glides noiselessly along mountain slopes. However, the eagle seldom succeeds in taking a young ibex by surprise. Older ibexes are probably too agile to be endangered by the great bird, but they are by no means unconcerned by an eagle's presence. I have often seen an adult male attack a golden eagle and chase it from its perch on a nearby ledge.

Anybody who is not afraid of cold feet and hands and who is familiar with the dangers of the mountain winter will find it worthwhile to watch ibexes during rutting season. At the beginning of the season. the males appear restless. These bulky animals, whose every movement seems determined by sloth, suddenly come to life. They roam the mountains—in groups or singly—in search of females. Their dark, winter fur makes them conspicuous in the snow or against the brown, dry grass. They move at a fast pace or in moderate bounds. When they stop. they can often be seen raising one foreleg, almost like a bird dog, and holding that position for several moments.

The start of the rutting season is indicated not only by the restlessness of the males but also by a characteristic raising of their tails. The top of the tail is laid forward over the back. so that the white underside contrasts sharply with the dark, brownish-gray, body fur. A dark spot on the underside of the tail. indicating the location of glands, is especially conspicuous. Particularly during this season, fights of varying duration occur between

“KNEELING” TO GRAZE is but one odd posture of ibex. Rings on horns, best seen from side or rear, are like tree growth rings, indicate age of animal.

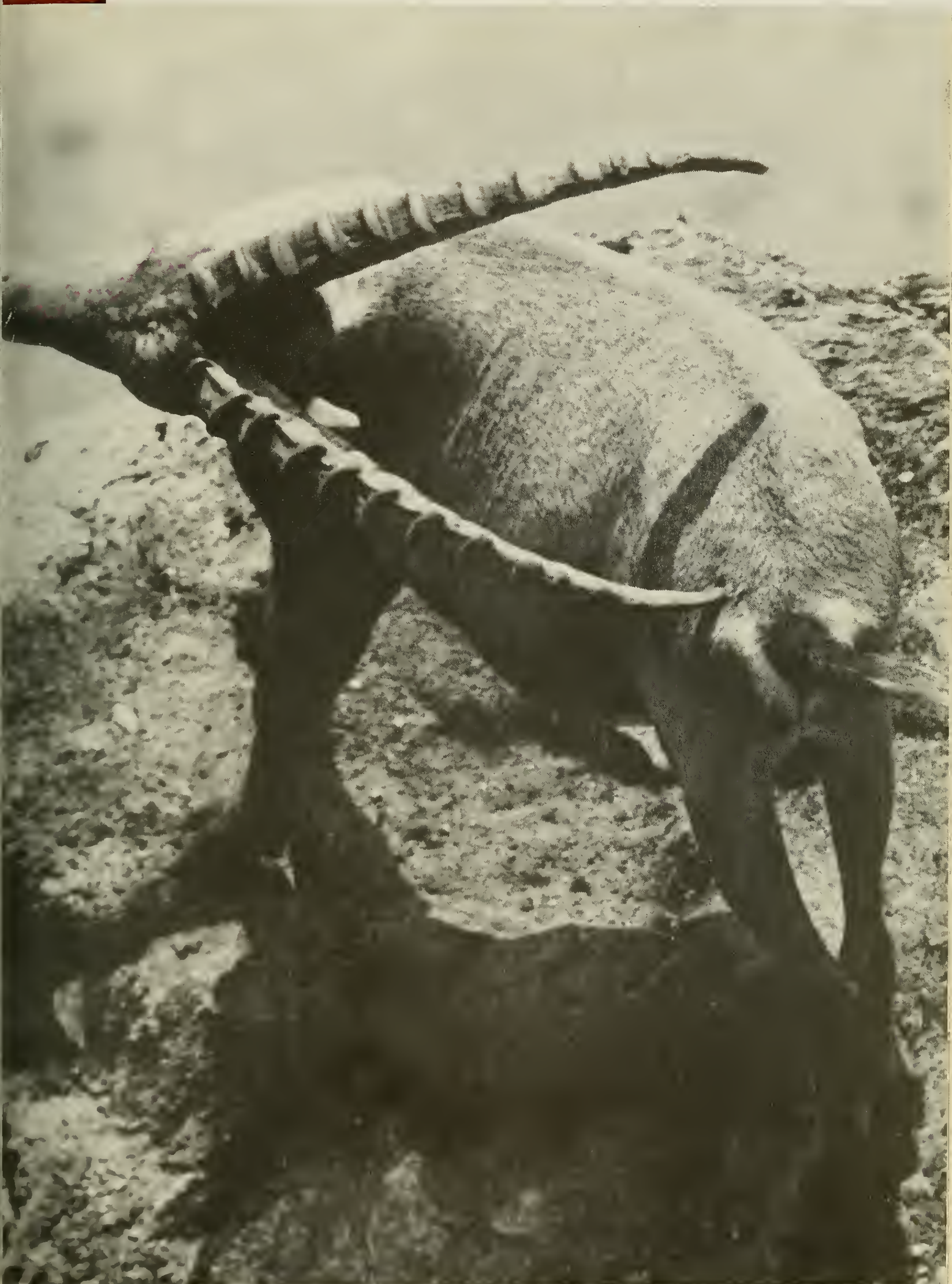
males of roughly equal strength. The fight usually begins with a frontal crossing of the horns, and continues with pushing in various directions. Then one or both males rise on their hind legs (as shown in the photograph on page 10), and the two heads clash noisily. As a rule the rivals separate after a few such exchanges. Once, however, I saw an extremely stubborn fight. In half an hour, two old males thundered their heads together 178 times—in such a manner that from my observation point, more than half a mile away, each blow sounded like the crash of a wooden plank against the surface of a pool of water. Then they separated as if nothing had happened. Frequently, nothing more than a threatening toss of the head is sufficient to chase away a weaker riv l.

During this season, the male proaches the female in typical ting posture: the head is raised i a horizontal position, the horns e lowered to the rear, and the neck s stretched far forward. Frequently, e remains in this position more than n hour, standing behind the female a a distance of from one to two yar . Other suitors wait in a long line hind him. The strongest male sta s nearest the female, the next strong follows and, at the end of the line, e may find some one-year-old ma . Seen at a distance, only their post e shows that they are males. This que of suitors seems to make little impr sion on the female. When the fo most male becomes too impudent, e female lowers her head and punc s his neck or sides with the tips of r thin horns. The male then retre s and waits at a respectable distan . In view of the great difference in b size between male and female, it s droll to see the ardent male suitor a ing much like a henpecked husba .

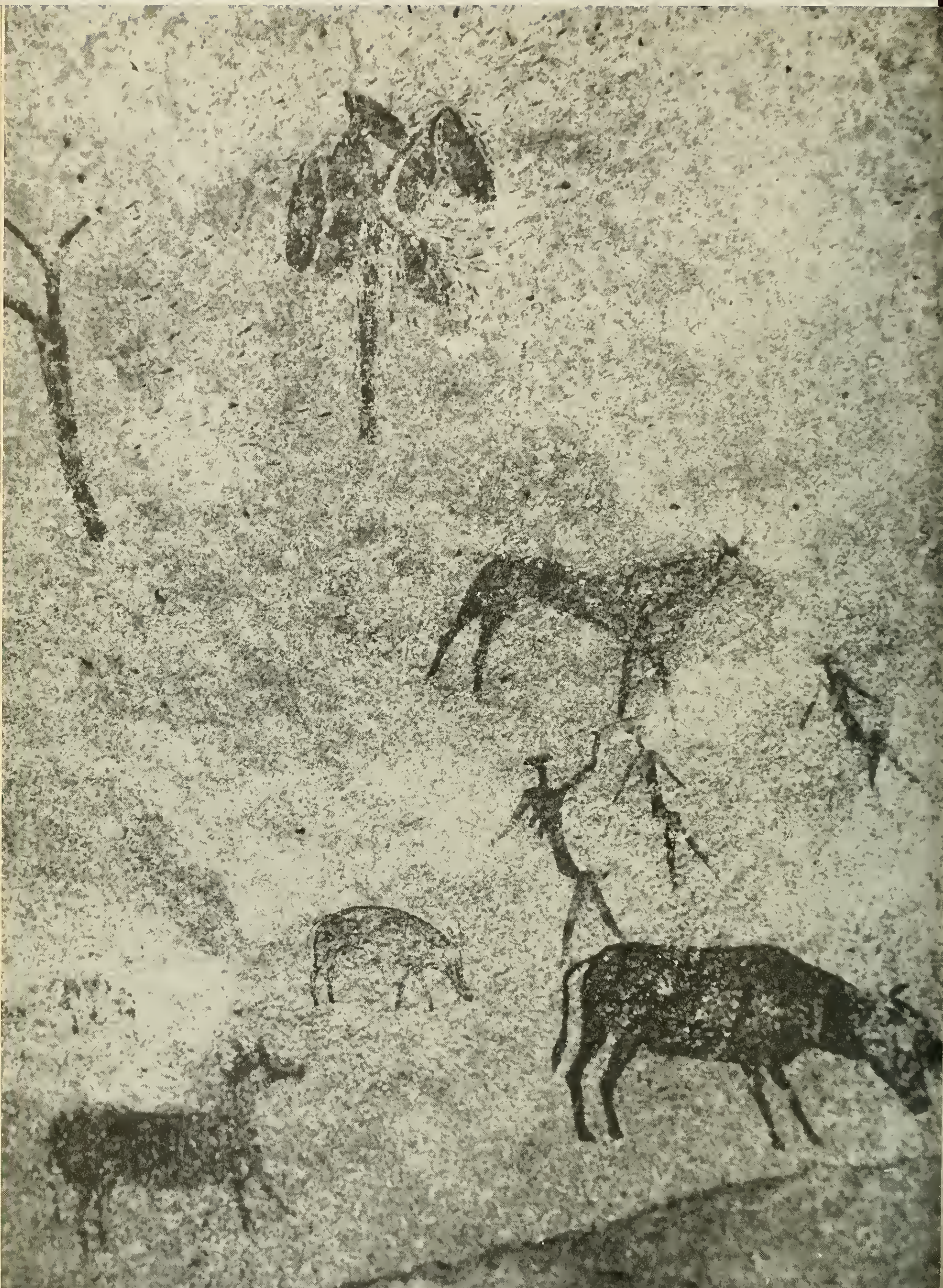
SHORTLY before the female is rea to mate, she changes her attit toward the males. Again and ag she flees, followed by the line swains. At breathtaking speed. group races across rubble and roc Over and over again, the fem eludes her pursuers by changing direction of her flight unexpected The old males seem to profit least these tactics. They are unable to f low the nimble females and youn rivals at such a rapid pace.

The herd life of the males duri the rutting season and their collect courting differ from the behavior all other Central European artiod tyls (red deer, roe deer and cha ois). This behavior enables the ib to live during the winter, and even the rutting season, in the limit space of slopes exposed to the su Thus, the social behavior of the ib may indicate an adjustment to its sp cial habitat. Whoever is lucky enou to have a chance to watch the ibex the freedom of nature will be fas nated by the animals. He will und stand why our Paleolithic ancest immortalized the ibex in their ca paintings and sculpture. We m all be grateful to the far-sighted p tectors of nature who succeeded preserving these remarkable Alpi creatures from impending extincti

DECORATIVE RIDGES on front of young male ibex’s horns are seen clearly in head-on view. As animal ages, ridges wear down and become less pronounced.



PLYING HIS HORNS to a dilemma, an ibex scratches near e base of his tail with apparent ease. Animal uses horns as grooming instruments as well as weapons, and, if length of horns permits, ibex may comb both flanks simultaneously.

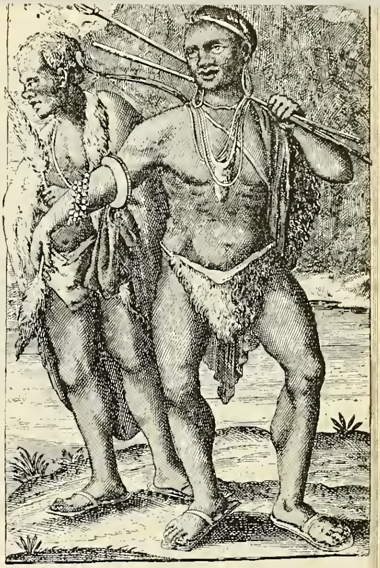


Bushmen left records of their lives in rock paintings such as this from the Mrewa Cave in Southern Rhodesia. At top are trees and rain; below are three running female figure the first one brandishing a digging stick—and four anima

Physique of A Desert Folk

Genes, not habitat, shaped the Bushman

By Phillip V. Tobias



Engraving of 1738 shows ornaments and dress of Bushmen of that period.

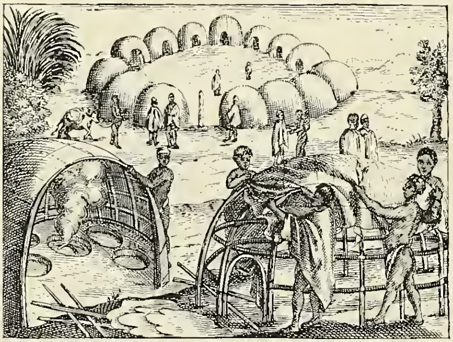
I THE DESERT WASTES of the Kalahari today live a people—known a the Bushmen—who are among the s angest of human races. He who v tures into southern Africa's hint land may well stand in wonderm nt and question before them. W ence came these Bushmen? What f tors have helped them to remain a e in so inhospitable a terrain? H w does man adapt to life in a dese ? Does his bodily structure, his a atomy, change? What of his physio gy, the functioning of his body? D es that alter, to help him survive? W hatever his bodily structure and f ction, how does the Bushman's w y of life—his culture—alter in ad ting to arid conditions? Is ability t survive in the desert actually a sub t blend of all these factors? How l g does it take to adapt, anatomic ly, physiologically, and culturally t the rigors of desert life? And, fin ly, have the Bushmen been desert d ellers for a long enough period of t e to effect many or all of these post ated adjustments? These are the q stions we shall explore: perhaps w shall find at least a partial answer t one or two of them.

When Jan van Riebeeck and his b nd of Dutch pioneers stepped a ore at the Cape of Good Hope in 1 52, they found the land inhabited b little hunters whose speech was m rked by clicking sounds, and by s htly taller, cattle-owning herdsm n, also click-speakers, but with a d erent language. The hunters came t be known as Bushmen, the herdsm n as Hottentots. From the beginn g, the distinction made between t two was fundamentally a *cultural* c : the Hottentots differed from the B shmen in language and way of life. To confuse the picture, groups of the hunters and some of the herdsmen had taken to living along the shores of the subcontinent: they became fused into a third group—the Strandloopers—distinguished from Hottentot and Bushman, as their name betrays, by their beachcombing way of life.

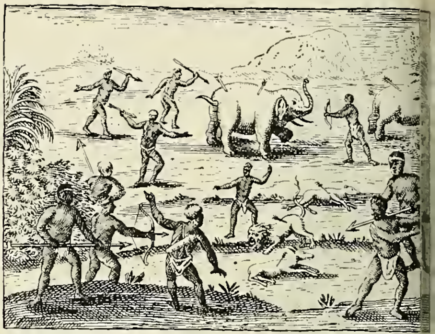
Such was the cultural skeinwork that bedecked large areas of southern Africa before the arrival of the Bantu-speaking Negroids and the white men—each with their own strange new culture. The racial mélange was even more complex. Were the Bushmen a different race from the Hottentots? If each was a distinct physical type, what was their relation to each other and to the Negroes? How did the Bushmen compare with the other little people of Africa, the Pygmies? And how were all these living groups related to the fossil men whose remains have been found in both South and East Africa?

The problem might have been relatively easy to solve, if a physical anthropologist, equipped with modern knowledge and techniques, had landed from the *Goede Hoop* with van Riebeeck more than 300 years ago! As it was, by the time a serious study of these peoples began in the twentieth century, the picture had been confused by a history of exterminations, hybridizations, and migrations scarcely, if at all, equaled in any other part of the world. White men arrived in slowly increasing numbers; Bantu-speakers pressed southward in their millennial advance down the east coast of Africa: West African Negroes were imported as slaves, as were Malayans—adding an exotic, Mongoloid drop to the mixture. Thousands of Bushmen were exterminated for the crime of hunting the strangely peaceful beasts of the white settlers. Hottentots fought Bushmen; white men pursued Hottentots; Hottentots retreated before Bantu; Bantu were in conflict with Whites; and all the while, as by-products of enslavement and conquest, novel experiments in miscegenation were being conducted among the Caucasoid, Mongoloid, Negroid, and Bushmanoid contestants. A whole nascent race, the Cape Colored, was born of this era. Today, that population numbers 1,300,000 and comprises the third largest racial element in South Africa. New tribes—with such names as Bastards and Griquas—were thrown up by these unprecedented mixtures of human genes. Older tribes, like the Gonaqua, were completely annihilated or, like the Korana, brought to the verge of extinction by intertribal warfare. In 1950, for example, there were only three hundred Korana—all that remained of the twenty thousand estimated to have been alive as late as 1850.

In this racial and tribal maelstrom, we can catch glimpses of the Bushman as some sort of living fossil: Paleolithic survivor in a hostile world of metal, farmlands, domestic animals, property rights—and firearms. We see



Huts of early Bushmen were made of saplings covered with sun-dried, closely woven reed mats that kept out the rain.



Short-handled, spearlike weapons with poison on their i n tips were used by Bushmen to hunt large game and wage r.

him being forced before the combined pressures of Whites, Negroes, and Hottentots into the most arid parts of the subcontinent, those regions of the Kalahari Desert that no one really wanted. So the Bushman, in fairly recent times, became mainly a desert dweller. It is important to remember how recently all this happened, especially when we wish to find out what sort of adaptations desert dwellers undergo.

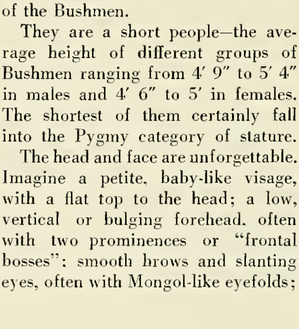
THE Bushmen have long been regarded as a vanishing race. More than thirty years ago, anthropologists were mourning the disappearance of a "few scattered groups still lingering in the Kalahari Desert." "In a few years," wrote Elliott Smith, a leading British anthropologist, "the world will know them no more." In his classic work, *The Khoisan Peoples of South Africa* (1930), Professor I. Schapera placed the total number of Bushmen still in existence "at a conservative minimum" of seven thousand to seventy-five hundred. This figure is still quoted today although, in 1939, Schapera published the greatly increased estimate of thirty thousand. Appearing at the outbreak of World War II, Schapera's 1939 revision did not become widely known. As recently as 1948, the late Sir Arthur Keith estimated that only about six thousand Bushmen still survived.

Current demographic estimates, however, suggest the presence of some thirty-one thousand Bushmen in Bechuanaland Protectorate, twenty thousand in South West Africa and smaller numbers in Angola, Rhodesia, and the Union of South Africa—an estimated total of some fifty-five thousand! The fact that so many are alive today testifies that these little, yellow people must once have swarmed over the face of Africa in numbers hitherto undreamed of and unexpected.

What manner of people are these Bushmen? Anatomically, they constitute one of the most distinctive of human types: so distinctive, in fact, that many scientists have seen in them a peculiar physical form of mankind, resulting from life in the hot desert. Before examining the truth of this view, let me try to paint a word picture of the Bushmen.

They are a short people—the average height of different groups of Bushmen ranging from 4′ 9″ to 5′ 4″ in males and 4′ 6″ to 5′ in females. The shortest of them certainly fall into the Pygmy category of stature.

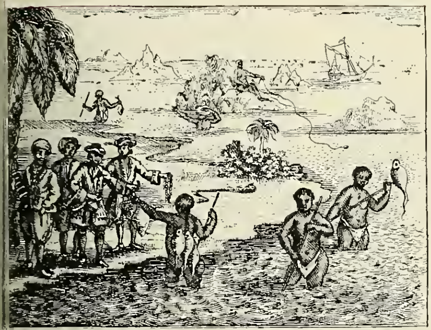
The head and face are unforgettable. Imagine a petite, baby-like visage, with a flat top to the head; a low, vertical or bulging forehead, often with two prominences or "frontal bosses": smooth brows and slanting eyes, often with Mongol-like eyefolds; very low or even flat nasal bric e. with a delicate, slightly elevated p to the nose; and angular, promir it cheekbones. This is a face witl a nearly vertical profile, generally la k ing the jutting jaws or prognathisn f the Negroid peoples of Africa. e small jaws house little teeth—usu y worn down, even to the gum mar n, but seldom showing carious de y. The lips are not thick by Afri n standards. The face's narrow forehe d. pointed chin, and projecting che kbones give it a characteristic diam d shape. The ears are tiny, with a he vily overrolled helix, or margin, d generally without any free lobe. e head hair is highly spiralized d tufted. Hair on both face and bod is sparse. The color of the skin is yell ish brown—considerably lighter t n that of the Bushman's neighbors, e Negroid tribes of Bantu-speakers.



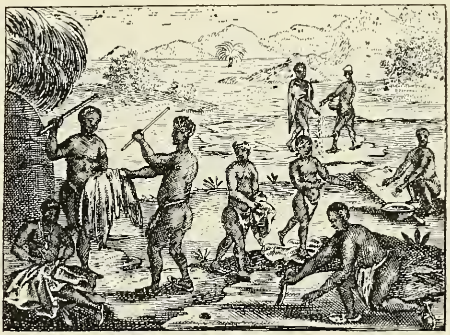
Hunting gear included spear, quiver, bow and arrows, and a clublike stick.

THE pelvic region is marked y appreciable accumulations of at over the buttocks (steatopygia), d over the thighs (steatomeria). Th e fat accumulations have been like d to the hump of the camel or the il of the fat-tailed sheep; the idea s arisen that the accumulations con itute reserve food stores, to be ca d upon in times of need. Steatopy a has thus been described as an adap tion peculiar to the difficult conditi s of life in the desert.

There are reasons for doubt g this interpretation. First, rock pa tings of Bushman-like figures, exhi ting unmistakable steatopygia, occu n many lush and well-watered parts f the subcontinent. Clearly, theref e, steatopygia has not been confined o



Coastal Bushmen were skilled fishermen, early explorers reported. They used nets, rods, spears, and even bare hands.



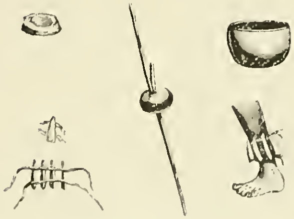
Animal skins were sun-cured and made into distinctive capes, into women's leg rings and many other decorations.

desert regions. Second, if the food-storage theory were correct, ought we not to expect male and female Bushmen to show the feature to an equal extent? Yet steatopygia is *always* much more marked in women. However, it may be argued that this differentiation was an adaptation to assist the women in meeting the serious nutritional challenge of childbearing. But no one has yet observed a *reduction* in the amount of steatopygia with pregnancy. Third, it has never been demonstrated that the amount of fat on thighs and buttocks is reduced after a bad season or a drought. Finally, although steatopygia, literally, means "fat buttocks," it is more in the Bushmen than a simple mass of fat. Long before the fat starts accumulating, there is a marked hollowing of the back, coupled with a throwing-back of the sacrum bone at the base of the spine. This "sacral shelf" is already present in infants. Although the fat starts to mass on the shelf only at the time of puberty, receiving further increments in the female with her successive pregnancies. Thus, steatopygia has both a postural and a fatty basis.

For all these reasons, a simple nutritional explanation of steatopygia is suspect. The accumulation of buttock and thigh fat at puberty and the sexual differentiation in amount of fat point to a link between steatopygia and the sex endocrine glands. This suggests that selective breeding may have played a significant role in the development of steatopygia. All over Africa south of the Sahara, large buttocks are prized: nowhere is this more evident than among Bushmen and Hottentots. "We like our women that way," say the Bushmen. Is it possible that we must invoke the now somewhat disused notion of sexual selection to explain the origin of steatopygia? To demonstrate the point, one would need information on the relative numbers of males and females, and the amount of competition for spouses, at the time when steatopygia first developed. Such information being impossible to come by, this hypothesis, unfortunately, must remain unproved.

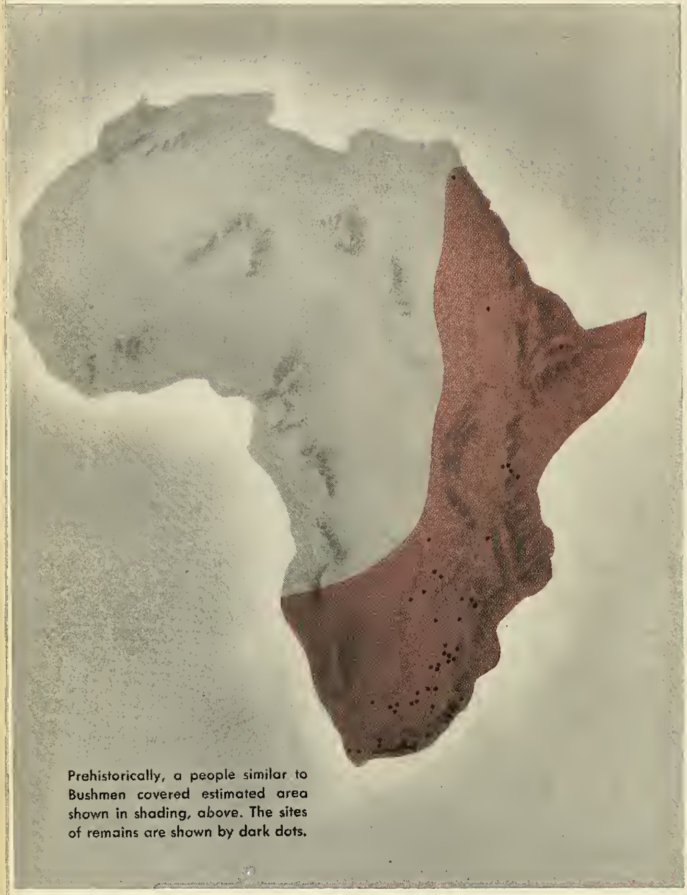
The fantastic enlargement of the *labia minora*, known as the "Hottentot apron," is another unusual feature of Bushman female anatomy. No one has suggested this as a desert adaptation: perhaps, here too, sexual selection has played a part. Whatever the explanations may be for these anatomical features, this, then, is a picture of our Bushman, unique in the family of man in Africa. Yet, although so distinctive, the Bushman shows some features in common with the Negro. Blood-group studies, which have proved so useful a tool in the determination of racial affinities, confirm that Bushman blood has many typically African features, while, in other regards, it shows a pattern peculiar to Bushmen. This may suggest that, long ago, Bushman and Negro might have had a common ancestry. It is hard to take this beyond a suggestion at present, because we have virtually no recognizable fossil remains of the ancestors of the Negroes, although we know a good deal about the forebears of the Bushmen.

In most anatomical features differentiating the two groups, the Bushman structure is closer to that of a child. The low, flattened skull; the poor development of his sinuses; his tiny mastoid processes; his bulging or vertical forehead; his small, flat face; the wide distance between his eyes; the flatness of his nasal bridge; the light skin pigment; hairlessness; the short, normally semierect penis with compact, high scrotum: these and many more features suggest that the Bushman has carried into adulthood a number of anatomical features normally associated with the infantile anatomy of any race.

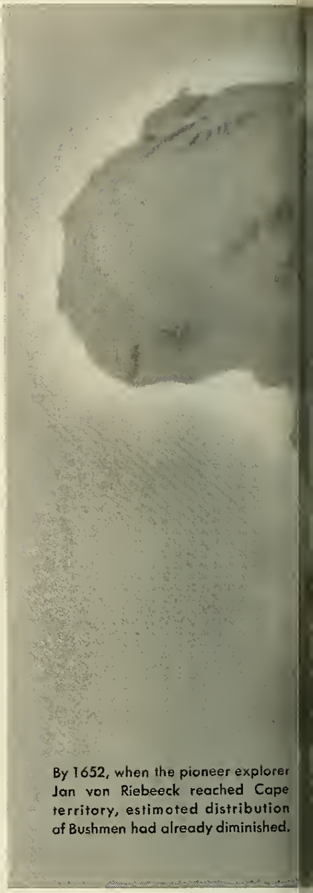


Other belongings were clay cooking pots, digging sticks, and dance rattles.

At some stage in the evolution of Bushmen, we therefore assume, changes occurred that resulted in retarding the development of certain bodily structures, without affecting either sexual or mental maturation. Such retention of infantile anatomical features into adulthood is a well-known phenomenon in the animal kingdom, generally known as neoteny. It has been suggested that neoteny was an important factor not only in the transition of an apelike ancestor into



Prehistorically, a people similar to Bushmen covered estimated area shown in shading, above. The sites of remains are shown by dark dots.



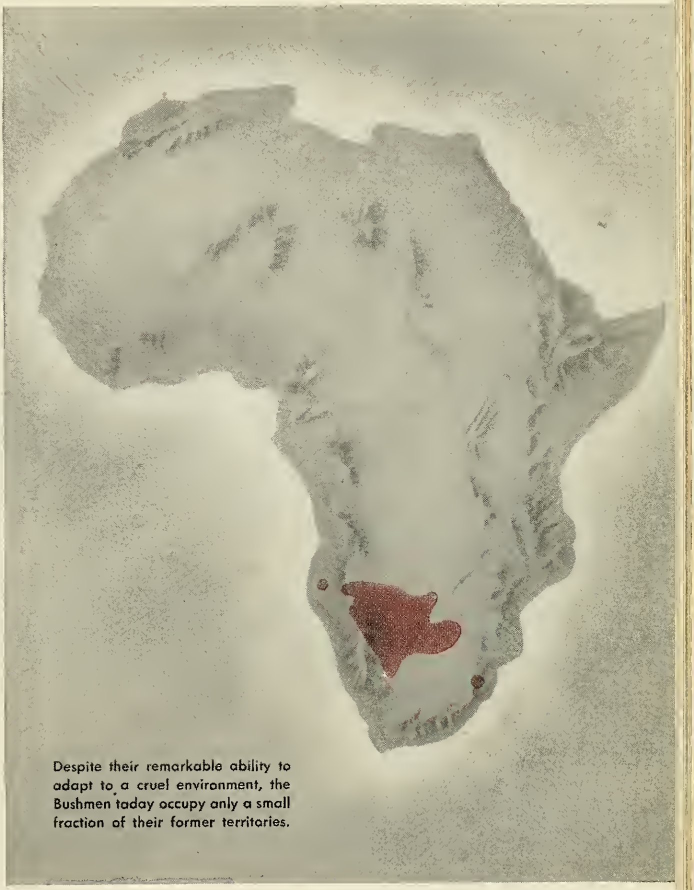
By 1652, when the pioneer explorer Jan von Riebeeck reached Cape territory, estimated distribution of Bushmen had already diminished.

a member of the family of man but also in the formation of various of the human races in that family.

THE advance of genetic knowledge permits us to offer a new explanation of neoteny in terms of gene action. The genes, the material or chemical basis of our biological inheritance, produce their effects by altering processes of embryonic development. Some alterations are qualitative, such as the formation of a new type of pigment; some amend the timing, direction, or speed of a process. A large class of mutant genes either accelerates or retards developmental processes, thus indirectly modifying the ultimate finished product. If the mutant gene operates early in embryonic development, it may affect a variety of developmental processes, and its impact may ramify through many parts of the embryo's body. Hence, instead of postulating one gene for flat nose, another for pentagonal skull, and a third for eyefolds, we can visualize clusters of features resulting from relatively few retarding or accelerating mutations. It is suggested that neoteny may be based on such key genes controlling varied developmental processes.

Is it possible that such changes resulted from the adaptation of the Bushman to desert conditions? The late Dr. Robert Broom believed that the Bushman was the "degenerate, stunted descendant" of larger people who had deteriorated under desert conditions. This view does not bea close scrutiny, however. From cave and open burial sites all over souther Africa have come skeletons that ar typical of the modern Bushman. Thes remains have been found over a wid range, far beyond the bounds of th desert regions. In fact, most of ther have come from such well-watered r gions as the southern Cape forest be and the Natal uplands. Similar ske etal types can be traced, too, right u through Rhodesia to East Afric Anatomically speaking, then, the Busl man was a Bushman long before h was pushed into the Kalahari Desert

The fact that the Bushman deve oped his infantile features before h became a desert dweller rules out th possibility that neoteny in any wa

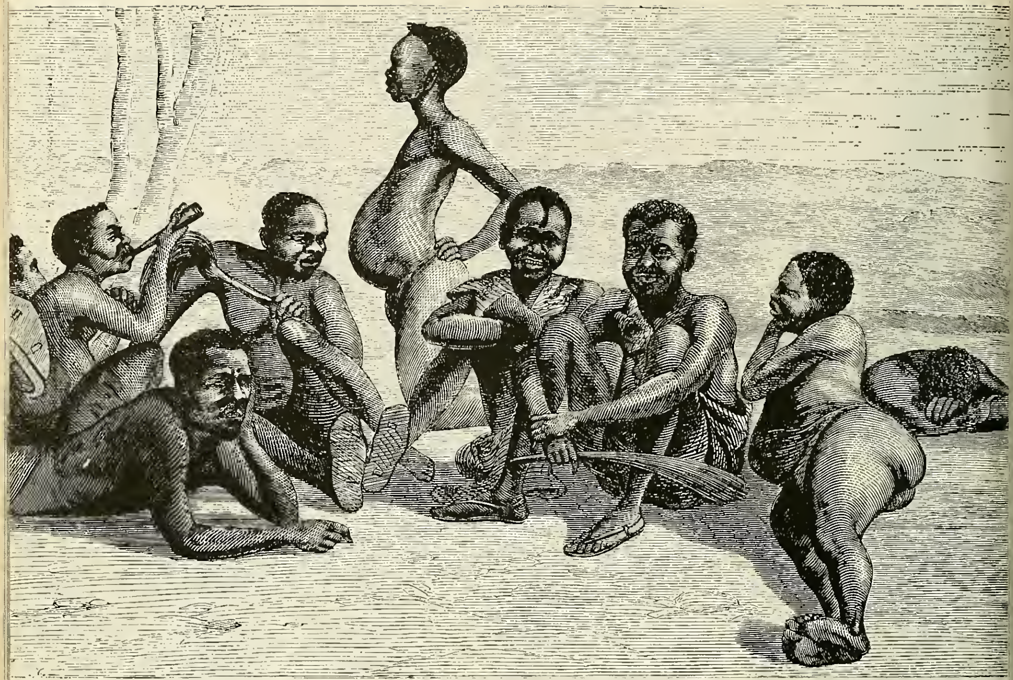


Despite their remarkable ability to adapt to a cruel environment, the Bushmen today occupy only a small fraction of their former territories.

adapted the Bushman to desert life. We cannot even say that neoteny is an adaptation to the hunting and food-gathering way of life, for there are hunters and food-gatherers—the Australian aborigines, for example—who show no infantile anatomical features. Why the development-retarding genes should have been selected in the ancestors of the Bushman remains a mystery. It is difficult to conceive of any especial advantage that neoteny conferred on people in a Pleistocene African setting. The Negroes of Africa avoided infantile specializations in a similar setting, yet have flourished over large parts of the continent. Whether there is some subtle tie-up among African climes, trace elements and other food-minerals, retarding and accelerating genes, the secretions of the endocrine glands and the degree of bodily development remains a fascinating and pregnant speculation.

The ancestors of the Bushmen, as the skeletal evidence demonstrates, also underwent a dwarfing process. Infantile structure and small, Pygmoid stature do not necessarily go hand in hand and some of the ancestors of the Bushmen combined their infantile anatomy with *large* stature. At different times, it seems, these early Africans underwent two kinds of change—development-retarding changes and growth-retarding changes. The archeological evidence shows that the last step in the formation of the Bushmen was this tendency toward the dwarfing of larger ancestors. Dwarfing, too, has been regarded as a result of life under desert conditions. Again, this theory is contradicted by the former widespread distribution of Bushmen in some of the most fertile parts of southern Africa.

LATE Pleistocene dwarfing in Africa was not confined to man. Dr. M. D. W. Jeffreys has assembled data on a variety of wild and domesticated mammals of which dwarf forms exist today. Examples include pygmy buffalo, antelope, hippopotamus, elephant, dormouse, leopard, and chimpanzee, in addition to dwarf cattle, goats, and sheep. Earlier Pleistocene deposits contain fewer dwarf forms and more giant forms. It is possible that late Pleistocene conditions in

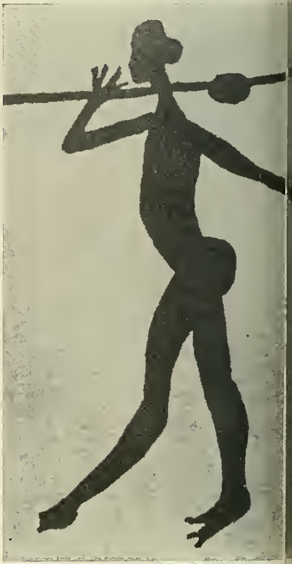


Strange Bushman anatomy—specifically, fat accumulations on buttocks and thighs, *above*—has been exaggerated as a possible aid in adaptation to the environment. Nineteenth century artist also indicated reputed laziness of Bushmen

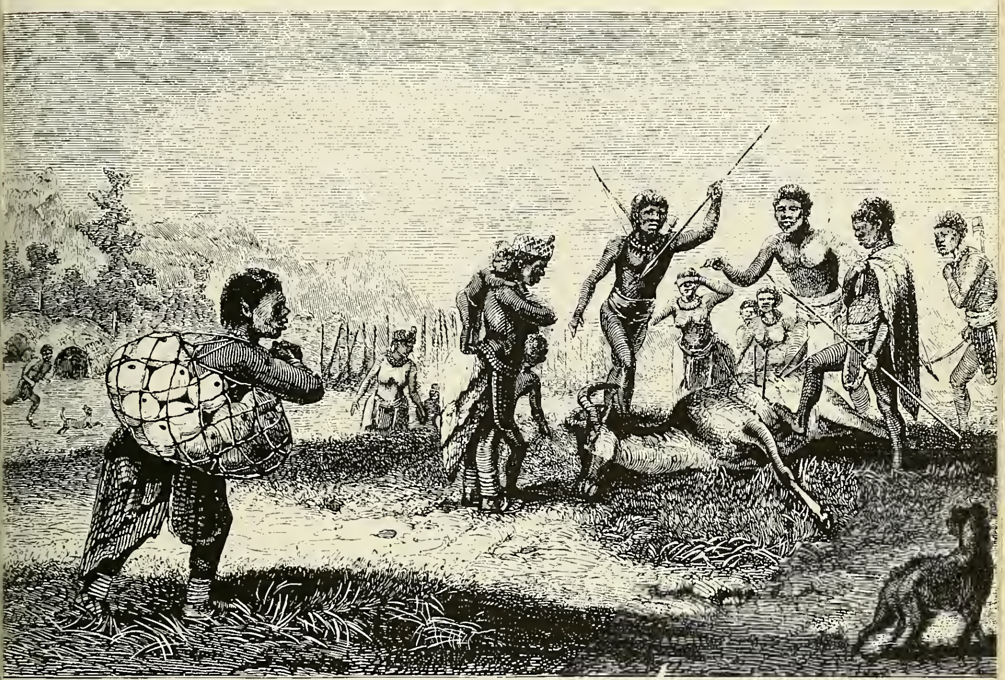
Africa may have favored and strongly selected dwarf forms, and that human dwarfing in Africa may best be viewed against this background.

With dwarfing, as with neoteny, it is possible that the effect was mediated through the pituitary gland. An underactive pituitary during growth and development may result in both infantile features and dwarfed statures. Pituitary midgets, for example, show many infantile anatomical features. What is a sporadic occurrence among Whites, however, is the rule among Bushmen and Pygmies—with the important difference that infantilism in pituitary midgets affects the reproductive system, so that sexual underdevelopment and even sterility commonly occur. Another difference between pituitary stunting and that of the Bushman is that the midget combines infantilism and dwarfing, whereas the ancestors of the Bushman became infantilized before the onset of dwarfing changes. So, although the Bushman's structure superficially resembles that due to an underactive pituitary, clearly a different sort of process is involved. Even steatopygia has been blamed on an out-of-step pituitary, but the curious thing is that steatopygia may develop in a white woman with an overactive pituitary (acromegaly). Even stranger are the bony changes produced in acromegaly: the skull becomes heavy-browed and overgrown, to produce a picture not far from that of Neanderthal man, whose anatomy was poles apart from that of the Bushman.

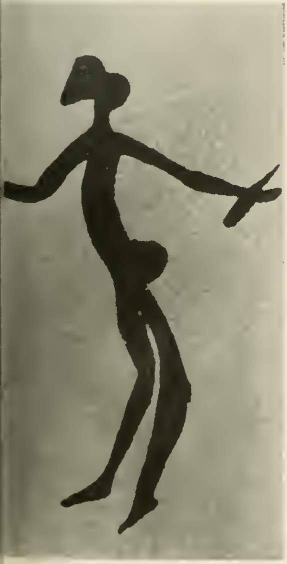
Here, too, it seems that we would be oversimplifying the picture of Bushman structure if we were to attribute steatopygia to hyperpituitarism. Despite the contradictions, this series of resemblances and contrasts leaves a strong feeling that, somehow, the balance of internal secretions in the Bushman is different from that of other types of man. Recent studies have shown a differentiation between the endocrine pattern in Negroes and that in Whites. Perhaps a fruitful field for future research will be to



Steatopygia is clearly shown in th rock paintings from well-watered area



Iottentots' living patterns resembled those of Bushmen. hey, too, downed game with short spears, wore capes made of skin, and carried bows and arrows. Both enjoyed ostrich eggs, and used the empty shells, in net, *left*, to carry water.



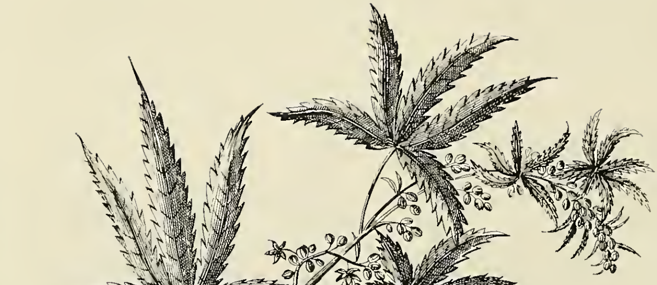
roving that Bushman physique clearly redated people's move to arid desert.

investigate whether the hormonal pattern of the Bushman, in turn, is different and whether such a pattern can explain the specialized features of Bushman anatomy.

Neither the Bushman's Pygmoid stature, infantile anatomical pattern, nor steatopygia, then, seems to be attributable to adaptation for a desert life. This is not to say that the Bushman shows no anatomical adaptations whatever. J. S. Weiner has shown that the Bushman's body build, as reflected in his height-weight ratio, differs little from that of other African peoples living in hot, though not desertic conditions. People in hot climates tend to have a lower body weight than those in temperate and colder climates. Coupled with this lower weight, a relative increase of body area makes for a much greater cooling surface relative to body weight. This feature the Bushman shares with other Africans. He also shares a broad, low nose, which seems to be correlated with external climatic conditions.

In brief, while the Bushman shows some general African adaptations to hot climates, the very structural features that make him racially distinctive from other Africans are not attributable to desert adaptation. He differs in this respect from the residents of the high Andes, whose response to their environment Marshall Newman has summarized (NATURAL HISTORY, January, 1958).

GENETIC adaptation is probably a long-term process. Acclimatization, however, is a shorter-term adaptation of the physiological processes within each individual. Preliminary tests show that Bushmen are well acclimatized to high temperature and fairly intense radiation—to both of which their way of life and habitat expose them. Man adapts to heat by an increased volume of sweat, by greater dilution of the sweat to conserve precious salts in the body, by a decrease in the heart rate during activity, and by dilution of the blood. Individual acclimatization applies to white men settling in the Tropics and,


Cannabis minor & lignofior. Bangua dicta.
Raj. Hist

PIPE-SMOKING WOMAN suckles child on her back. Her "tobacco" is probably from dagga plant, *left*, which was also used medicinally to treat snake bites.

probably, to Bushmen as well. Such internal adjustments, which affect the individual's body during his lifetime, help Bushmen to cope with hot conditions in the Kalahari.

THERE is yet a third means of adaptation available to man: he is able to undergo cultural "acclimatization," and adapt his way of life to the conditions of his environment. This process is far swifter and simpler for resourceful man than either the random and long-term process of genetic adaptation or shorter-term, physiological adaptations. Man's plastic culture enables him to don fur-lined clothes and to heat his dwellings in cold climates; he does not need to grow a hairy skin to survive an ice age! Indeed. man's biological evolution has, in large measure, given way to cultural evolution. No longer is he the victim of his physical milieu: more and more is he able to control his environment and, especially, those parts of it that formerly dictated the direction of evolutionary change.

A few examples will show how the Bushman has adapted his pattern of existence to his historically recent way of life as a refugee in the desert. To protect himself from undue absorption of solar radiation and from the desiccating effects of hot, dry winds, he coats his skin with animal fat or blood and accumulates a crust of Kalahari sand on the surface. This protective mail assists his physiological adjustments to extremely hot conditions. So thick and dark may this layer be that the unwary observer doubts, at first, that the Bushman is as light in skin color as reported. A vigorous cleansing of a small ar necessary before the anthropol can attempt to read the true skin c

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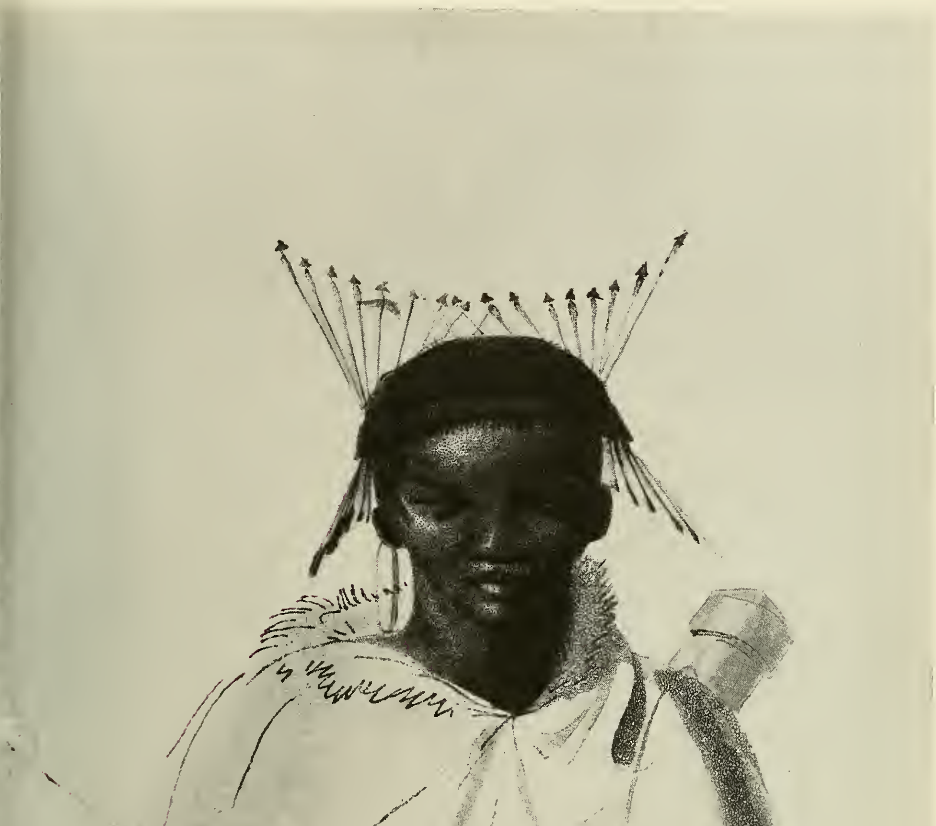
THIS "mud pack" treatment o skin is a cultural adaptation helps the Bushman cope with hea is his technique of water storage. rainfall is sudden and sporadic earth blossoms briefly. The Bush stores all the water he can in e ostrich egg shells and calaba carefully burying them in the earth against a later day of th Further, as part of his diet, he great quantities of water-rich pl such as the fruits of the tsamma m *(Colocynthis citrullus)*, the Gem cucumber *(Colocynthis naudinian* and other species of plants that sess juicy storage organs.

Another cultural adaptation h him to cope with the cold wi nights of the desert. Experiments ried out by Dr. C. H. Wyndham his co-workers have shown that t is little difference in the *physiolo* response of Whites and Bushmen posed to identical conditions in Kalahari. Culturally, howeve Bushman makes skillful use of frail hut. his fire, and his skin c to create a microclimate about self. This microclimate proves measurement to be only a few deg below the thermo-neutral zone of to 30° C. for naked man at rest. cultural adaptation carries the B man through the cold, wintry ni of the Kalahari Desert.

OUR final picture. then. is people whose curious. ge cally controlled anatomy plays part in adapting them to desert whose physiological responses a matize them to hot, dry conditi and whose cultural pattern fi makes it possible for them to bea extremes of heat and cold that cha terize their harsh environment. the Bushman, it is not too much to that we see epitomized the stage man's evolution—from slow, st tural, genetic adjustment. thr smooth and reversible functional commodation, to swift, intellig cultural adaptation and, with this, final mastery of the world around



DE CHEEKS, taper to pointed chin give Bushman's face classic, triangular conformation. This portrait of "A Bosjesman in Armour" appeared in a travel book written by English explorer John Barrow, published in early 1800's.

Before jumping, two frogs sit on brick platform in the photographer's aquarium in normal position—hind feet folded under body, eyes everted.

A Bullfrog and Its Prey

A look at the biomechanics of jumping

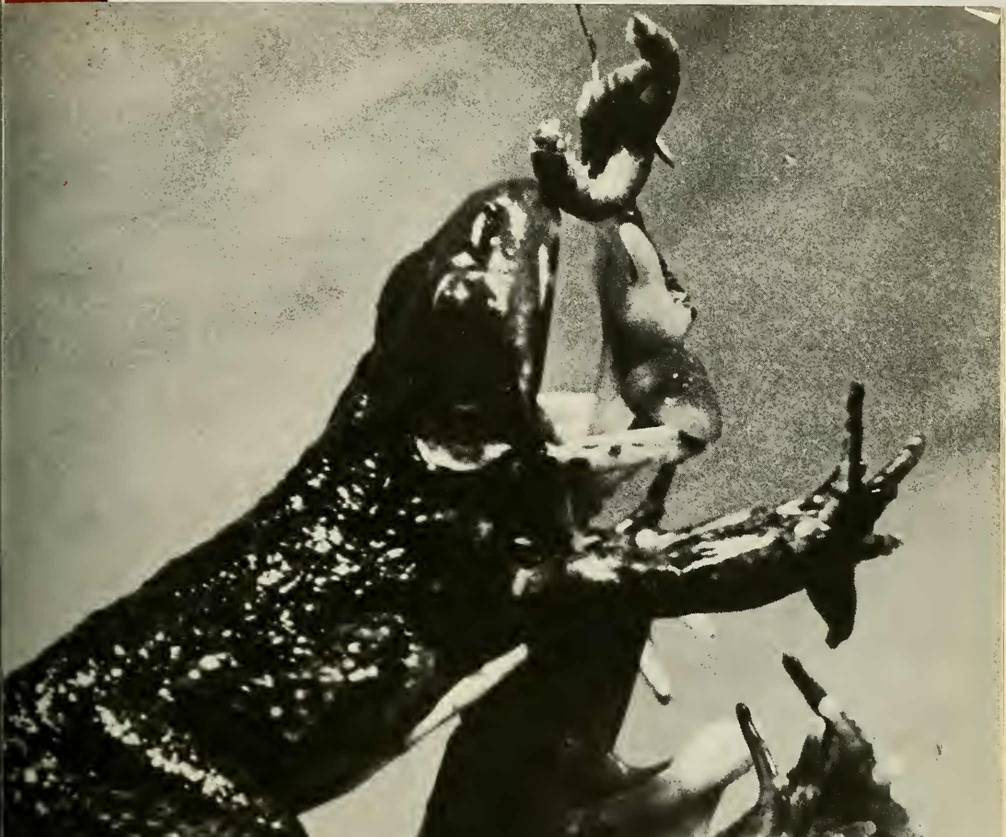
By Carl Gans

The frog has the unenviable distinction of being one of the most commonly used laboratory animals. Hundreds of manuals and dissection guides testify to its popularity, and hundreds of thousands of research papers investigate it. In spite of the frog's popularity, however, there is only a handful of scattered items dealing with its most characteristic attribute—its jump.

The photographs of *Rana catesbeiana*—the common bullfrog—accompanying this article are thus of particular interest, since they represent a concerted attempt to record such jumps at prey with modern photographic techniques. They are the work of Mervin F. Roberts, a civil engineer and an amateur frog fancier, although he can hardly be called an amateur photographer.

Bullfrogs will jump at "flying" prey from land or water. In order to permit focusing of his camera, Mr. Roberts trained his frogs to jump from a brick on one edge of a tank at bait suspended some ten inches away and four to five inches above the water surface. Best response was obtained when live and moving insects and worms were used as bait. Interestingly, the frogs generally refused to jump in bright light but would usually launch themselves immediately after the lights had been dimmed.

The jump at bait took approximately 0.3 seconds from launch to splash. Ordinary stroboscopic flash units with a flash duration of 1/1000th of a second proved insufficient to stop all movement during the critical tongue eversion, and a special unit with a calculated flash duration of 1/10,000th of a second was obtained. The unit was triggered when the moving frog passed the light beam that led to a photoelectric cell.



OUTH IS OPEN before frog's tongue, attached behind tip f jaw, is everted, as is demonstrated by two frogs jumping simultaneously. Apparent in near frog is the way in which hind legs can be twisted to influence the jump direction.

Suspension of the bait caused some initial difficulty. Live animals had to be held firmly, yet be easy to remove. The suspension had to keep the bait from swinging out of the range of focus determined by the camera, and at the same time have virtually no inertia at the moment the frog hit the bait. A metal V, located just above the tank and open in the direction of motion, kept the bait from drifting with minor drafts without offering resistance when the frog hit. Pictures taken with the modified setup showed the prey capture did not significantly change the jump path.

It may be useful to say a few words about the animals involved before starting a discussion of the jumping process. The Salientia, or frogs, are a diverse and cosmopolitan order of amphibians. Most live in the tropics or subtropics. Workers recognize five suborders, eight families, and some forty subfamilies among the recent species, yet our vocabulary has but three terms for frog types—frog, toad, and tree frog. This, of course, reflects the impoverished frog fauna of England, where our language originated. It is clearly impossible and undesirable to force this arbitrary trifurcation on the multiplicity of frogs. It is just as foolish to think of frogs as representing but three modes of life history. Some frogs lack a protrusible tongue, others prefer a walk to a jump, and many of the suggestions gleaned from these photographs are applicable only to the genus *Rana* or even to the species *R. catesbeiana*.

Just as varied as the purely structural characteristics are those aspects of behavior that directly reflect the pressures of the environment. Some arboreal frogs seem to jump at prey only if the continuation of the jump will bring them into contact with another branch or group of leaves. They will often jump at sitting or walking insects, striking them at the same time they grasp the leaf. This suggests the disadvantage of a drop to the forest floor—even though such a drop would easily be survived. Many true toads rarely deign to jump at any flying prey except low-flying, slow-moving forms. The characteristic feeding movement involves a stalk of crawling or walking prey, and ends in an amazingly well-directed tongue-flicking movement. Evidence suggests that toads generally strike at the front end of a crawling worm, perhaps because the swallowing may be easier when the worm is eaten head first. No one seems to have checked whether it is instinct or learning that governs this element of toad behavior.

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The nature of the jump is just as distinctive. Many aquatic and terrestrial frogs move in a series of short jumps, particularly when traveling over rough or grassy terrain. They seem able to leap high enough to surmount the densest vegetation, and to do much of their horizontal travel between the grass stems. The more-or-less pointed head apparently helps deflect chance contact with stems and leaves. Arboreal forms more often combine a walking climb with the standard jump; some characteristically hang with legs partly and asymmetrically extended in quite monkey-like poses. Most forms can and do use their limbs alternately under special circumstances, such as when burrowing or pushing their way through densely woven vegetation.

In many cases the maximal jumps are elicited by some sort of avoidance or fright reaction. Every boy knows that the best way of making a frog jump is by touching its rear. Here, again, there are decided differences between forms. Certain species flee toward the nearest water in a continuing series of straight-line jumps. Others progress away from the water, and still others have been observed to jump up a sharply inclined rock wall, and then disappear into crevices. Interesting, too, are a number of species that will suddenly leap at right angles to their previous direction of motion. Most of these jump patterns are instinctive, although aspects thereof may perhaps be modified by learning.

The change from a walking to a jumping method of locomotion probably represents the fundamental functional shift in the development of a "froglike" animal. All other changes probably came later.

Progression by walking is derived with some modification from an alternating or undulating mode of progression, which is probably the basic and most fundamental swimming movement. The elongate body is thrown into an S-curve by the asy metric contraction of the trunk m cles on the inside of each S-be Forward movement is caused wh forces exerted on the rear surface the loops pass backward along body. When the body is immers these forces are exerted against water; on land, the push is agai surface irregularities. Where fins limbs are present and used with t motion, they will be moved alt nately on the front and rear of op site sides (left-front, right-rear, rig front, left-rear). There is some e dence that this pattern is primiti since alternate motion can be p duced by activating the limb musc at the time the contraction wave the body muscles reaches the lim point of insertion. The nerves th supply the motor stimulation of limbs are modified from the ner that activate the trunk muscles the level where the limb originat

When such a tetrapod mov slowly, it has three feet in cont with the ground and the fourth in m tion. As the velocity of travel rises diagonally placed pair of limbs mo simultaneously. This leaves only t feet on the ground, and the positi of the body is kept in a kind of d namic equilibrium by its inertia. the same manner, a runner's bo will continue along a more or l even path with alternating assista from his two pumping legs. Such undulatory motion is often facilita by elongation of the body and ta This acts to extend the distance alo which the S-curve can act. It a tends to counteract lateral forces, that the head does not swing too from side to side and returns to desired line of motion.

The frog's jump shows a high velopment of a relatively primit jumping pattern. The animal alwa starts from the same sitting positi which it apparently must resume fore each leap. There is little, if an continuity of motion or elastic pick at the end of each bounce, and may think of the animal as progre ing by a series of standing hi jumps. The power for propulsion generated by the *simultaneous* acti tion of both hind legs. This is basic departure from the ancestral *ternating* limb movement.

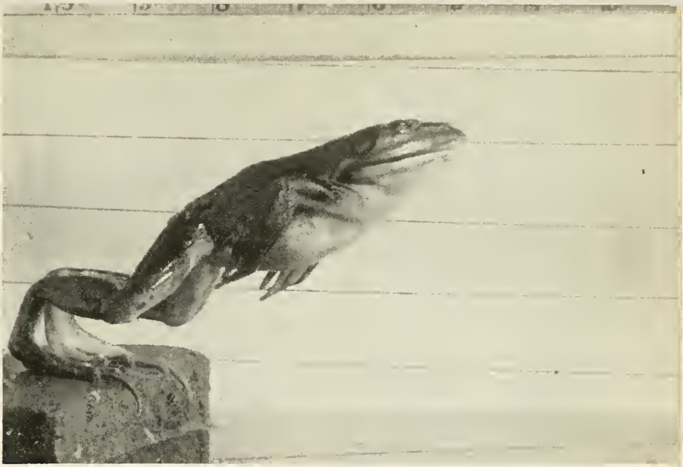
It is of interest to speculate on evolutionary origin of this simul neous movement of the hind lim

Jumping movements, produced by a variety of often rather inefficient mechanisms, are commonly noted as escape mechanisms of salamanders and fishes. Jumping combines three advantages: first, a rapid, unpredictable, and hence confusing movement; second, he elimination of a continuous olfactory trail, so that predators hunting by smell have difficulty following the path; third, the confusion of sight-hunters caused by the abrupt cessation of movement. However, some workers—among them Hans Böker, a German student of such matters—suggested that the simultaneous motion of the hind limbs was derived during the preterrestrial (aquatic) and prejumping stage of frog ancesry. According to this hypothesis, the simultaneous motions of both hind eet drive the body forward in a traight line and facilitate pushing he head, or burrowing, into masses of vegetation. It was felt that this traight motion avoided the swinging movements of the head that might mpede penetration.

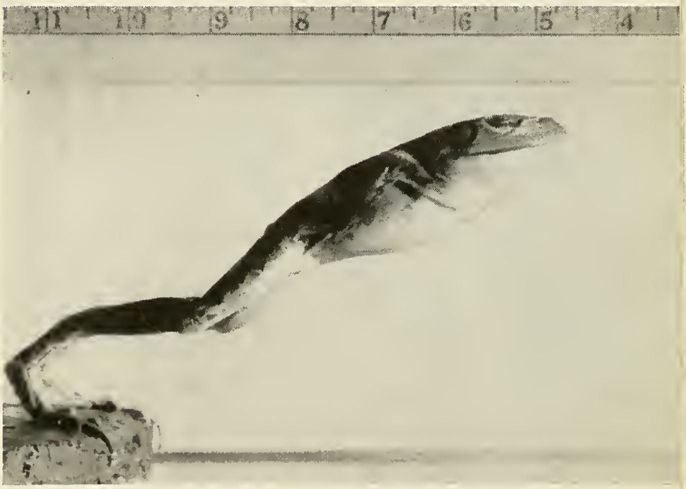
ALTHOUGH it seems probable that the prefrog stage may have been passed in the water, Böker's argument s weak. Many fishes and salamanders —the eel and siren are spectacular xamples—manage to combine an efficient burrowing existence with an undulatory system of locomotion. It eems as logical to assume, for intance, that jumping forms an initial daptation for a quick return to the water from which the frog had merged by alternate locomotion. It s unfortunate that we know only a few steps in the complex origin of rogs, and that fossil remains seldom ermit behavioral decisions.

Once simultaneous movement had een achieved, there must have been a apid modification of the entire body tructure. The tail was no longer eeded for propulsion or as a steering ar. There was no longer a premium n elongation of the body, which ould now be shortened to the limits nposed by the arrangement of the iscera and trunk musculature. The sulting increase in cross-sectional rea—same body volume for less ength—was compensated for by aditional emphasis on streamlining of he modified animal's head.

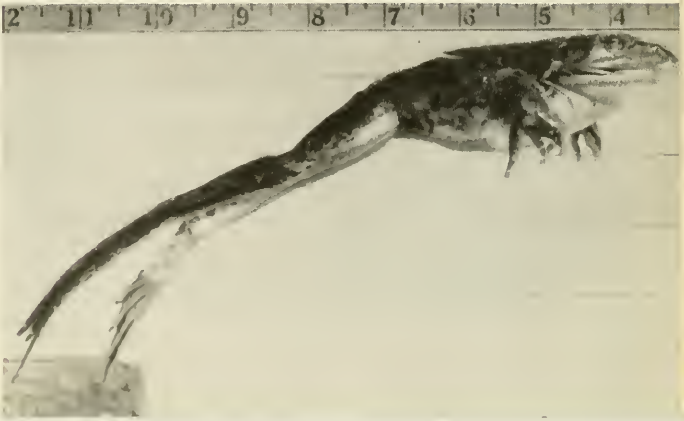
Each pair of legs of a quadruped may be thought of as a device for exrting a force against the substratum.



DIFFERENT JUMPS show characteristic movements. Eyes are closed, *above*, the forelimbs folded back, feet in contact with the ground. Note inch scale at top.



FEET still touch ground, *above*, and maximum streamlining is reached. As prey nears, *below*, the forelimbs come forward, toes are completely straight.



If the body is relatively rigid, there is little advantage in using both pairs for propulsion. Analogously, a car may be equipped with front- or rear-wheel drive, yet both sets of wheels are powered only under exceptional circumstances. Most terrestrial animals are limited because they must use all four legs for support, but aquatic animals can afford to concentrate most of their "drive" in a single pair of limbs. A short-bodied animal has a further advantage, as its drive is set as far to the rear as possible. In most aquatic species of frogs the region that has to exert the push is further concentrated by the development of large webs on the rear feet, supported and reinforced by the digits.

THE demands on the swimming apparatus seem to have provided the basic requisites for jumping—a sudden backward push by the hind limbs can project the frog upward and forward on land as well as in the water. However, in jumping it is necessary for a single backward push to produce a maximum of energy; it is no longer feasible to obtain additional velocity by a succession of movements. Therefore, it is not surprising that a variety of devices tends to increase the take-off velocity and to counteract any factor reducing it.

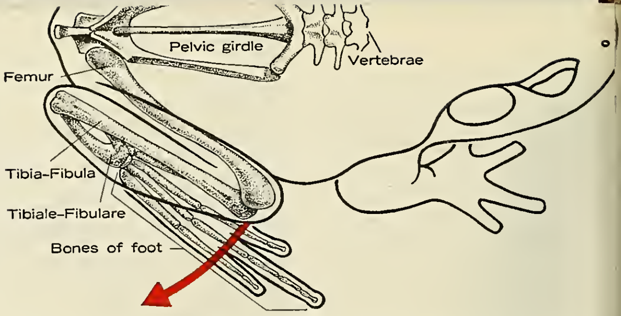
The take-off speed must be attained before the frog's toes have left the ground. Elementary ballistics teaches that the force (F) required to produce a given acceleration (a) in a body of mass (M) is:

$$F = M\,a$$

and that the acceleration is the difference between the initial velocity (v_0) and the final or take-off velocity (v_1) divided by the time (t) during which it is exerted, or:

$$F = M\,\frac{v_1 - v_0}{t}$$

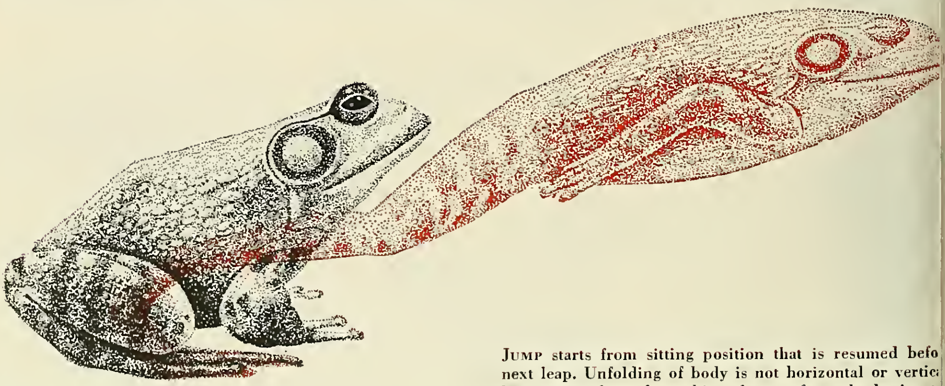
For a given jump, the mass and the initial and take-off velocities are constant. The force that must be produced by contraction of the leg muscles can only be lessened by increasing the length of time during which it is exerted. This is the same as increasing the length of the initial flight path during which part of the frog retains contact with the ground. The part of the frog in such contact remains stationary until take-off, and then has to accelerate suddenly to full speed at a much higher rate than the rest of the body. The energy for this has to be furnished by the inertia of the frog's body, and the frog's velocity consequently must be reduced. Hence, the lower the mass of the terminal parts, the less the over-all reduction in velocity. The continuous attenuation of the frog's hind legs, down to the thin and elongate toes, is admirably fitted to this requirement.



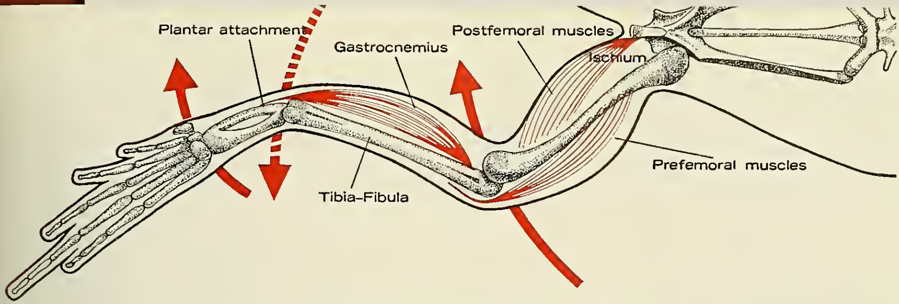
WHEN FROG SITS, several sets of long leg bones fold against each other. The elongation and folding of the hind l is one characteristic of other jumpe

In passing from the general pro lem of jumping to an analysis of M Roberts' photographs of the jump, is useful to take a quick look at the a rangement of muscles and bones the bullfrog's hind quarters. The have been diagrammed to emphasi the pertinent points. The diagra (page 31) shows an elongation of o set of bones in the frog's hind le These bones are the tibiale and the fi ulare, forming the heel in man a other forms, but here extended half the length of the foot. They arti ulate with the fused tibia-fibula (sh bones), with the remaining tars and, through them, with the dig (foot bones). The several sets of lo bones are folded against each oth when the frog is sitting. They unfo more or less simultaneously duri the jump, and are almost complete unfolded when the toes leave groun

THE elongation and folding of t hind limb is characteristic jumpers, whether they be grassho pers, frogs, or kangaroos. The long the legs, or the greater the number



JUMP starts from sitting position that is resumed befo next leap. Unfolding of body is not horizontal or vertic but is in a plane about thirty degrees from the horizont



ELONGATION of leg shows the bone and muscle formation. Muscles on posterior side of the femur rotate this bone and begin the needed acceleration. Muscles along femoral shaft rotate tibia-fibula, thus straightening the legs out again.

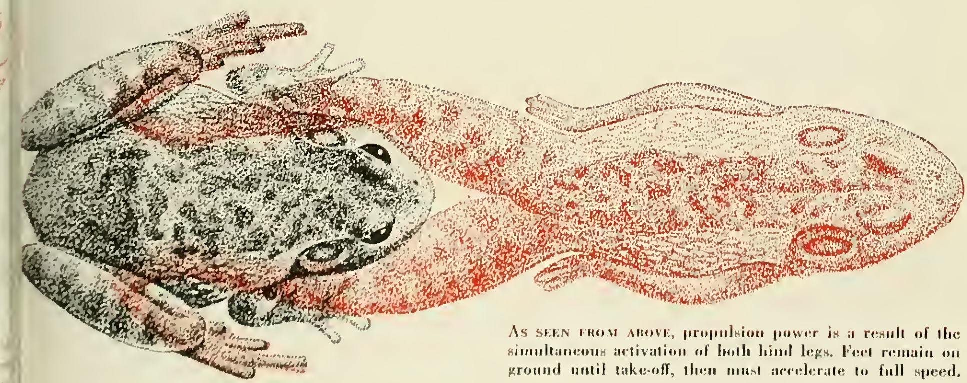
folds, the farther the distance and the onger the time through which the body may be moved while the foot still contacts and exerts a force on the ground. In bullfrogs this distance is greater than the body length. so hat a higher acceleration can thus be attained with less muscular stress.

PHOTOGRAPHS on pages 28 and 29 show that the process of unfold-ng occurs neither in the vertical nor n the horizontal, but rather in a plane some 30° from the horizontal. This supports the observation that the main muscle masses of the upper leg ie in front and behind the femur. Both of these major groups contribute energy to the jump. Only a few elatively smaller muscles power the eturn of the limb to rest.

The frog's use of two sets of large muscles, apparently antagonistic, for a single sequence of movements is urprising. The voluntary muscles of he vertebrate body are most often arranged in antagonistic pairs. Changes n their relative contraction may move he bones in one direction, in a reverse direction, or hold them stationary. Closer examination shows that the frog's muscles, though on opposite sides of the same bone, are not actually antagonistic. The first muscle group on the posterior surface of the femur connects the femoral shaft to the posterior plate of the pelvic girdle. Its contraction swings the femur through an arc of some 100°, so that the bone's free end points back instead of forward. The side photos actually show the bone pointing slightly downward during the jumps. The movement thus provides strong horizontal but little vertical acceleration. The second group of muscles originate on the femoral shaft and run along its anterior surface to insert on a set of flat tendons that attach to the shaft of the tibia. The tendon sheet runs over the femur's free end as over a pulley. Contraction of the second group of muscles rotates the tibia-fibula in a direction opposite to that of the femur, thus straightening the leg. The actual arrangement of the muscles is far more complicated than here described. For instance, some of the muscles lie behind the femur and attach to the tendon over the knee. However, it is apparent that the two groups are opposite in position, but not antagonistic in action.

The pattern of opposite, but not antagonistic, muscles continues down the leg, with muscle systems designed to power the shift of each bone upon the one closer to the body. The leg segments are folded around all joints, except those between tibiale-fibulare and the tarsals and digits. They lie in the resting position and straighten to provide the propulsive force. Between the tibiale and the fibulare the segments first fold and then straighten around the joint after the animal has left the ground in its jump.

THE unfolding of the several segments of the hind leg tends to propel the frog's body on the same principle as that used by some aboriginal spear throwers. Here the spear is propelled by a separate lever, held by one end and rotated. It is known that in operating a lever, the applied force is to the force exerted as the inverse



AS SEEN FROM ABOVE, propulsion power is a result of the simultaneous activation of both hind legs. Feet remain on ground until take-off, then must accelerate to full speed.

ratio of their distances from the fulcrum (the point about which the lever rotates). But it is also true that the distance traveled by a point on a lever rotating through a given angle increases with the distance of the point from the fulcrum. (During any hour the tip of the minute hand travels much farther on a church clock than on a ladies' lapel watch.) The diagrams on pages 30 and 31 show that this principle makes for a maximum shift of the body for a minimum movement of the muscles, which are attached very close to the fulcrum.

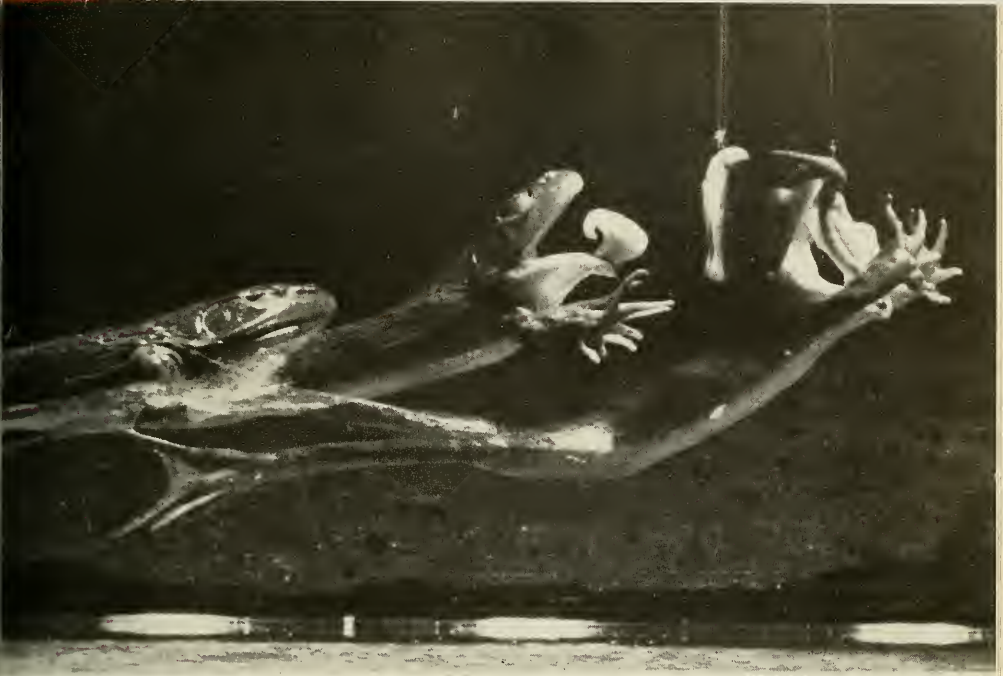
This seemingly inefficient muscle arrangement has been considered of importance for several reasons. Muscular contraction is not an instantaneous affair—it requires a definite time. However, during the moments before take-off, segments of the frog's limbs are moving at speeds in excess of six feet per second. A muscle arranged for maximal mechanical advantage would have to contract at least that fast to maintain the continuing pressure of the foot against the ground at that acceleration. It may well be that it is biomechanically simpler to increase the force than the contraction speed of the muscle. A second consideration is the fact that the force exerted by a muscle is reduced when the muscle is allowed to contract for a greater distance. The less the movement, the greater the force exerted. When muscles are attached close to the fulcrum, it is easier to attain the needed force and maintain it through a given angular movement of the bone. All of this should not mask the fact that there may well be reasons of geometry that overrule aspects of purely mechanical advantage. It is the adaptiveness of the entire organism, and not some special property of an organ, that is normally selected for in an evolutionary process of development.

The four photographs of the jumping sequence show some other ways in which frogs are adapted to efficient jumping. The forearms are folded backward against the body and the eyes are not only closed, but are retracted into the head. The frog can do this without trouble, as it lacks a bony separation between orbital and oral cavities. Both the arm movement and the retraction of the eyes would seem to be behavioral adaptations to jumping. They reduce air friction during the jump and protect these important structures from accidental damage during collision. The side views show the noticeable streamlining during the initial portion of the jump. As the jumping animal levels out, the forearms rotate forward and downward—though it is not yet known whether this motion is triggered by changed inclination or by some other signal.

The closing and retraction of the eyes pose some extremely interesting and as yet unanswered questions. It certainly appears as if the frog first "sees" the prey and then closes its eyes and jumps blind. Such a blind jump would cause the frog to miss a considerable percentage of erratically moving objects. There is evidence, however, that the frog exerts a continuing control over its flight path.

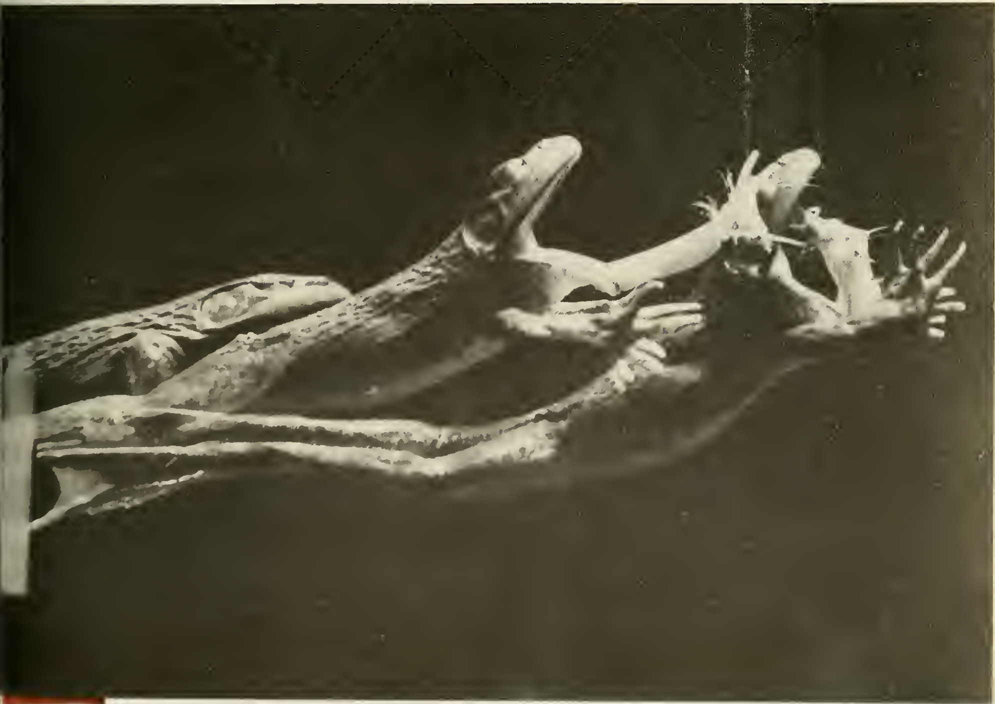
Some of the photographs show a sudden lateral shift of the jump path. (A vertical correction by the frog would be far more difficult to detect and confirm.) This shift or alteration of the path seems to take place fairly close to the prey, and has only been observed when a miss was imminent. After the initial and fortuitous observations were made, it proved possible to increase the frequency of "navigational corrections" by causing the bait to swing just before the frog's jump. This suggests that the frog may produce the shift by a change in the relative position of its hind legs, which swings the body round the center of gravity. Several remarkable photos (pages 27 and 37) show a frog apparently using the expanded membrane of the right hind foot to swing its body toward the prey.

A complicating factor in explaining this apparent control of the path is produced by the nature of vision in frogs. It has long been known that frogs show remarkably little response to immobile objects. Dead or anesthetized prey is ignored, even when the frog is hungry. A group of biologists from the Massachusetts Institute of Technology recently tapped the frog's optic nerve and found an explanation. Apparently the frog's retina does not see or report a mosaic image. Instead, there are groups of cells specialized in such areas as boundary detection. One particular group reacts to the curvature of an object, and may thus be considered to serve for "bug perception." However, the bug is perceived *only* if it is mov-



OUR-STAGE jump sequence, *above*, shows proximity of frog o bait before the mouth opens, and two stages in forward otation of the tongue. Small vertical rectangle at the left s mirror that triggered photocell as frog passed in front.

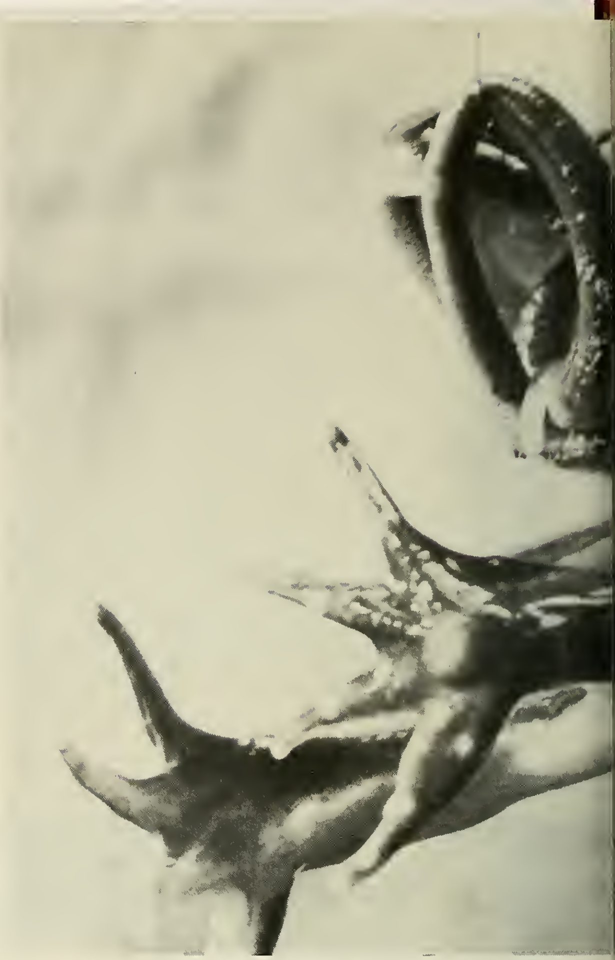
BENDING of lower jaw, caused by dropping of the symphysial bones, is demonstrated in sequence photograph, *below*. Also visible is rotating tongue base, and free tongue tip that attains own motion after base has performed full rotation.



ing. Immobility reduces the strength of the "sight signal" to the point where it will be wiped out and not reinstated if the object is momentarily hidden. It is not known whether this cessation of input implies the disappearance of the spatial memory of the object within the brain (if such a thing actually exists in a frog), or how quickly the disappearance might take place. If fading does occur, shutting of the eye might interfere with subsequent modifications of aim.

THE closing of the eye would not of itself cut off the image entirely. The lower lid, often called the nictitating membrane, is thick but transparent, and would seem capable of changing the optical qualities of objects seen through it. More important is the fact that the lid undoubtedly cuts down on the amount of binocular vision possible for a frog. Such binocular vision (looking at an object with both eyes simultaneously) is required for the initial aiming. It is not certain whether a bullfrog can start a jump in a direction at an angle to the one in which it is sitting. Many tree frogs can easily do this, but preliminary tests suggest that a directed jump by a tree frog will only be made in the direction in which the head is pointing. This seems to suggest that the aiming process involves some sort of equalization of the stimuli being received from the two eyes. Similar situations have been described in other animals that jump, or project part of their bodies. There is, for instance, evidence that the African chameleon must focus both of its independently operated eyes on an insect at the same angle before there can be assurance of a hit by its tongue.

These various bits of evidence allow a tentative hypothesis for explaining the frog's flight correction. The takeoff seems to be aimed visually and then the jump started with the eyes retracted. If the aim remains true, and the object remains in front of the nose, it will not move across the visual field. The reduced binocularity will make the object increasingly less visible as it approaches. However, a faulty jump registers the prey as a moving object on a single eye. The greater the distance between object and flight path, the earlier the moment occurs when the prey is clearly enough "seen" to trigger corrective action. This relationship would explain the last-stage changes in the flight path. It would also be interesting to determine if the frog has any distance—rather than only directional—judgment, or if it jumps at any object of a certain apparent size.



TONGUE EMERGES in 0.05 seconds, and whips around prey
a weighted rope end will spin around a post. Attachment

The jump carries the frog to the vicinity of the prey, which, however, must still be caught. The photographs show clearly that the frog does not open its mouth until it is within two to three inches of the bait. It then lifts the head, actually bending it backward on the neck, and drops the lower jaw. The tongue consists of a flat plate with a seemingly small tip on each side of the free edge. Curiously enough, this free edge points backward when the mouth is closed. The
tongue is attached just behind the ti
of the jaw and the photographs sho
it swinging forward around the a
tachment. At its most forward pos
tion it will have rotated through 180
If the aim was right the tongue wi
reach the prey before rotation is con
pleted. During the forward swing th
tongue will elongate and then wra
around the prey, much as th
weighted end of a swung rope wi
spin around a post. The retractio
occurs as quickly, and the tongu
carries the wrapped prey into th
mouth. The forelimbs may assist
stuffing in the ends of large or u
wieldy items, but the mouth closes b
fore the frog has traveled two inche

The speed with which this simp

prey is facilitated by tongue's elasticity, sticky saliva, and the many short papillae that catch on any irregularities.

rocess takes place has produced some remarkable confusions regarding its nechanism. Muscles do their work while contracting; they cannot *push* ut only *pull.* Push is generally exrted by having muscles linked to a igid structure such as a bone. The labby frog tongue lacks bony support nd reaches far beyond the mouth. Thus it cannot be pulled—yet somehing must move it.

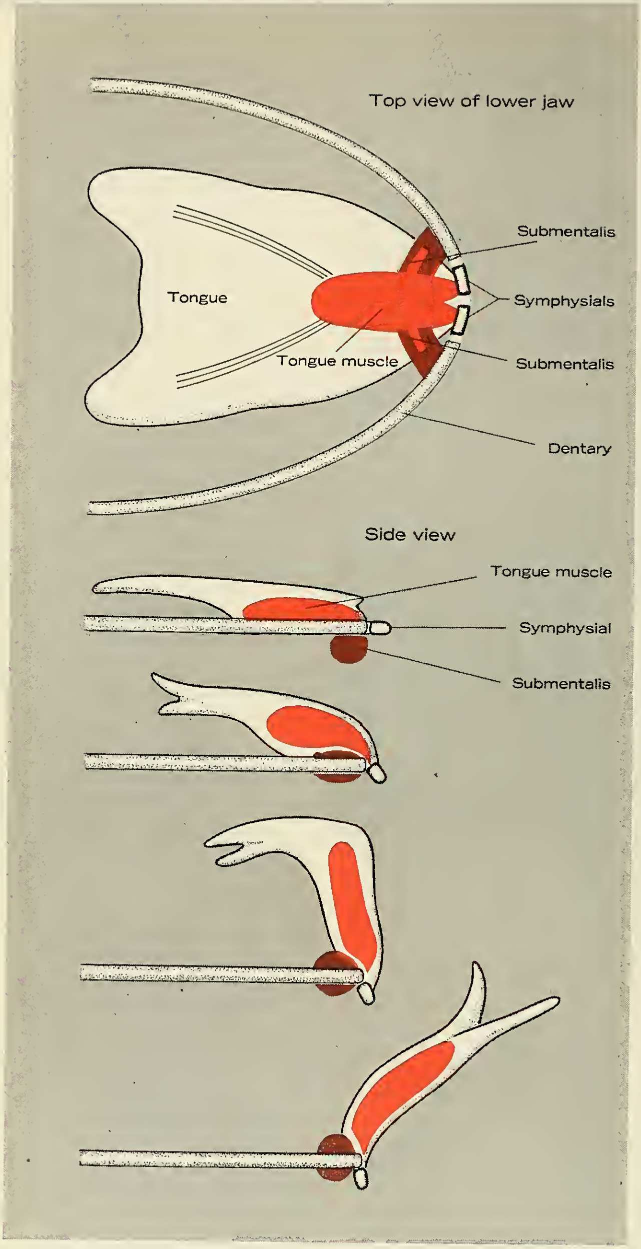
THE first anatomical report on the tongue seems to have been pub-ished in 1827 by Antoine Dugès, a rench anatomist who suggested that he work was done by muscles. Howver, he apparently lacked proper op-ical equipment, as his drawings show the smaller structures in the wrong places. Then in 1901 two completely conflicting reports appeared. The first was a detailed study by Gaupp, the man who had earlier revised the standard reference work on frog anatomy. He concluded that there were two sets of muscles, one that flipped the tongue outward and another that retracted it. The second report was a note by Hartog, who seems to have published it twice—in Paris and in London. He claimed that flipping was activated hydraulically by lymph, which filled large spaces within the tongue. He based his case on the amount of space filled and the action produced by the injection into the tongue of molten cocoa butter. One may presume that Hartog soon encountered and accepted Gaupp's study, because a promised longer paper never appeared. In spite of this, and of a careful restudy of yet additional forms by the Indian anatomist Gnanamuthu, and comments on its variation in different groups by the Russian anatomist Tatarinov, there are still many texts that refer to a hydraulically operated tongue. Some have added insult to injury by attributing the theory to Gaupp.

IT is not too difficult to prove Hartog wrong. The tongue emerges in 0.05 seconds and is retracted in less time than this—far too quickly to be hydraulically activated. His "large spaces" are artifacts, probably produced by excessive pressure during injection. What, then, is the muscular mechanism that flips the tongue?

Three separate anatomical facts and one well-known biological phenomenon enable the frog to flip its tongue. First is the pressure of a pair of loosely attached bones connecting the tips of the lower jaws. These symphysial bones are unique in frogs, but their true importance does not seem to have been recognized. Second is a stout muscle connecting the ends of the true jaw bones across the tip of the lower jaw. Third is an astonishingly large mass of muscle in the base of the tongue. This mass is attached to the symphysial bones in front and to nothing in particular in back. The posterior and lateral surfaces of the muscle mass are enclosed in a stout covering, but only two relatively small muscles connect the mass to the free portion of the tongue. These are the facts. The phenomenon, namely that muscles become rigid on contraction, is one familiar to every little boy who has demonstrated his incipient biceps to admiring members of the opposite sex in the schoolyard.

The reconstructed tongue-flipping sequence is as follows: the contraction of the cross muscle, or submentalis, draws the tips of the jaw bones together. This motion forces the symphysial bones downward, and with them the attachment of the large tongue muscle, which now bends in a quarter circle around the contracted submentalis. The simultaneously contracting tongue muscle begins to shorten and assume a straight line. It can do this by letting its "free" end move upward, thus achieving a rotat-

ing motion around the rigid bar
the contracted submentalis. The u
ward swing of the rigidifying tongu
muscle then carries along the body
the tongue, catapulting it forwar
The dropping of the lower jaw assis
this movement, and the tongue seem
to continue traveling by its own ine
tia. The tongue's elastic structure a
lows it to stretch so that it is almo
twice as long when extended as whe
resting in the mouth. A second set o
more conventionally arranged mu
cles pulls the tongue back into th
mouth, possibly aided by the inerti
imparted by the captured insect pre


Top view of lower jaw
Submentalis
Tongue
Symphysials
Tongue muscle
Submentalis
Dentary
Side view
Tongue muscle
Symphysial
Submentalis

Structure of frog's mouth is shown at top. When tongue flips forward, the submentalis draws tips of the jaw bones together, and forces symphysial bones downward. Tongue muscle swings up, carrying tongue and catapulting it out.

Near miss shows tongue is completely extended at end of jump's aiming point, and body is twisted to correct the aim.

Nictitating membrane can be seen over the retracted eye, in contrast to the everted eye of resting frog in water.

The stretching mechanism has the advantage of facilitating the tongue's attachment to prey objects. The tongue is covered with a viscous saliva, and bears a forest of short papillae that would seem to catch on irregularities while wrapping around the prey. Intimate contact with the prey is maintained by inherent elasticity, and before it can unwrap itself the insect or worm will be trapped inside the frog's closed mouth.

It was once thought that the sticky product of certain glands of the upper jaw was wiped off by the tongue as it traveled forward. Gnanamuthu had already published his doubts on this point. Now Mr. Roberts' photographs (page 33) show that the tongue does not touch the roof of the mouth during its forward path. One photograph is again worth pages of discussion.

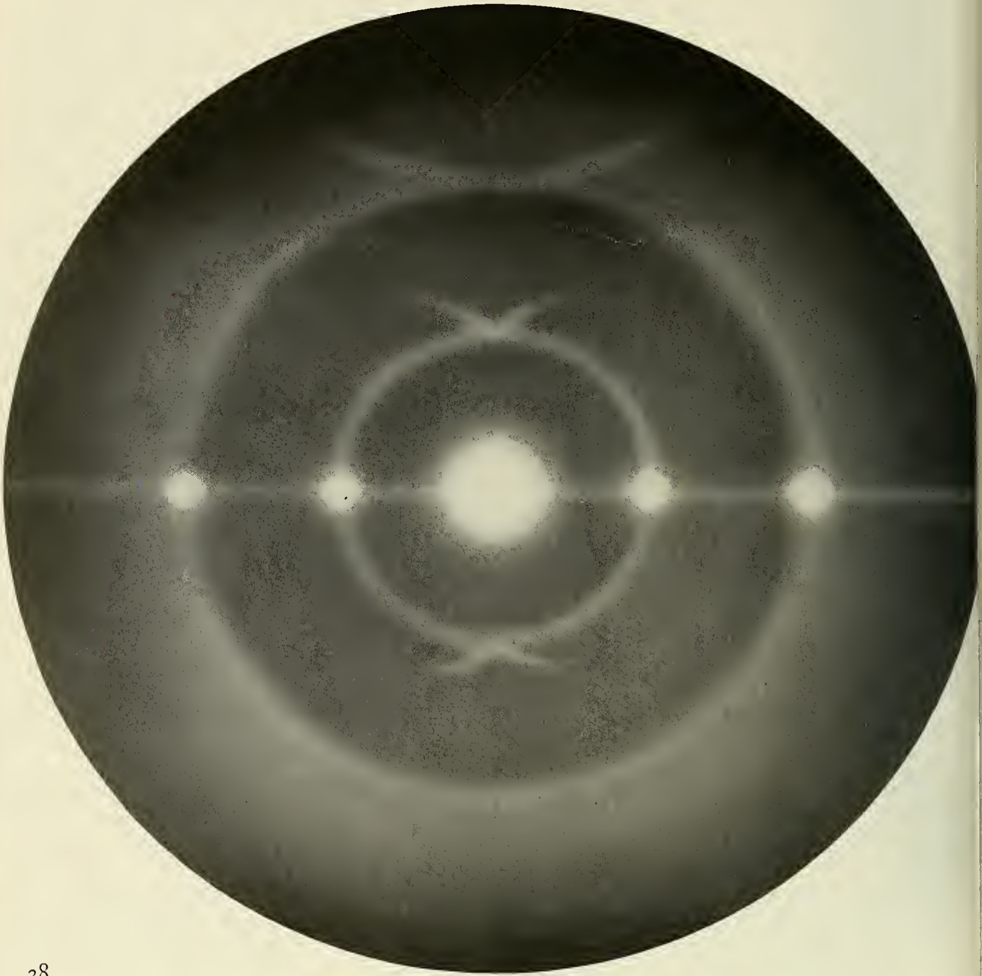
The tongue-flipping mechanism seems effectively designed to be operated during a jumping sequence. The use of a relatively elastic initial contact with flying prey reduces the chance of sudden shocks on the body. The speed of motion is sufficient to permit the prey to be caught and stuffed into the mouth before the frog hits the water. The bullfrog's size and construction allow it to survive even the most spectacular drop it might encounter normally. It may thus jump freely at any passing prey; the landing can only be more or less happy.

It is hoped that this brief discussion has helped to illustrate that some basic principles of biomechanics may be derived from a consideration of as prosaic an object as jumping and feeding methods of frogs. Many things remain to be learned, even about the commonest animals, and it is obvious that photography can considerably assist the learning process.

Light Reflections in the Winter Sky

Atmospheric phenomena once terrorized awe-struck observers

By Richard G. Beidleman



IT HAD BEEN A CHILLY NIGHT for April throughout the Severn countryside of southern England. As the barley sowers left their homes at dawn to start the planting, the sun, "following its orbit about the earth," rolled slowly up out of the eastern woodlands, bringing with it a never-to-be-forgotten spectacle.

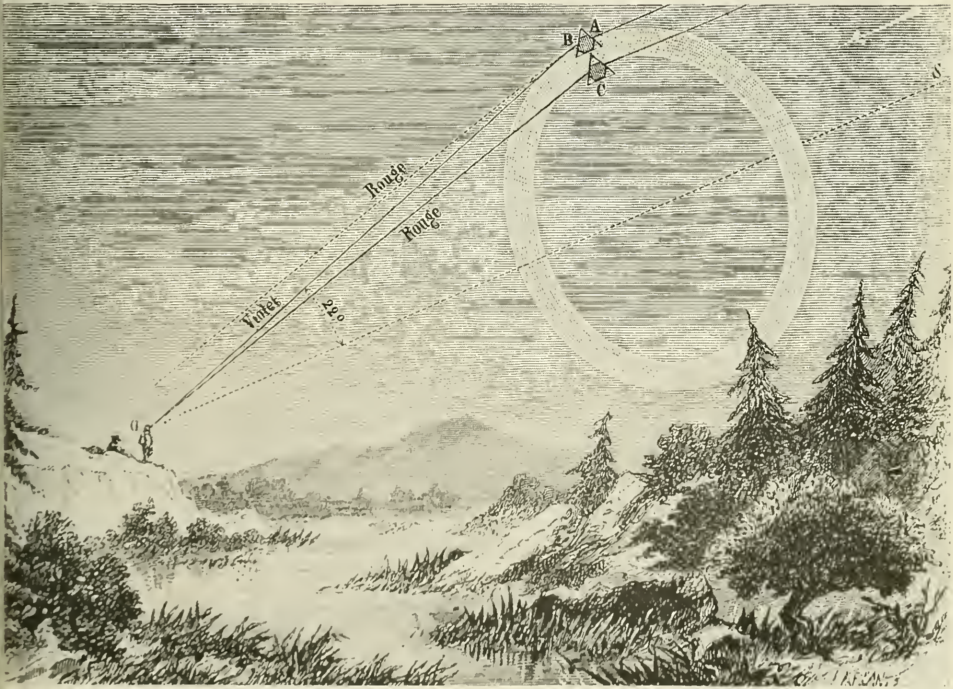
Wild thoughts must have filled the minds of the hundreds of peasants, yeomen, and gentry, who, in the year 1233, viewed the heavens with consternation. In the pale blue sky that reached across toward Normandy, moving in consort with the rising sun, were four celestial spheres of equal brilliance, flanking the sun in pairs. And passing through these paired spheres to circle around the sun were two broad and many-hued, encircling halos. From sunrise until noon, this prodigy rode the spring sky above England, then vanished as mysteriously as it had appeared, leaving bewilderment below.

Through the centuries, many such strange lights have been seen in the sky, ranging from simple halos to complex illuminations that vault the entire heavens, and all of them are associated with the vagaries of light rays in moisture-laden atmosphere. The term "halo" itself was introduced by Aristotle and is generally, though incorrectly, applied to any rings around the sun or moon. Actually, there are two major types of "celestial" rings, differing with respect to their mode of formation.

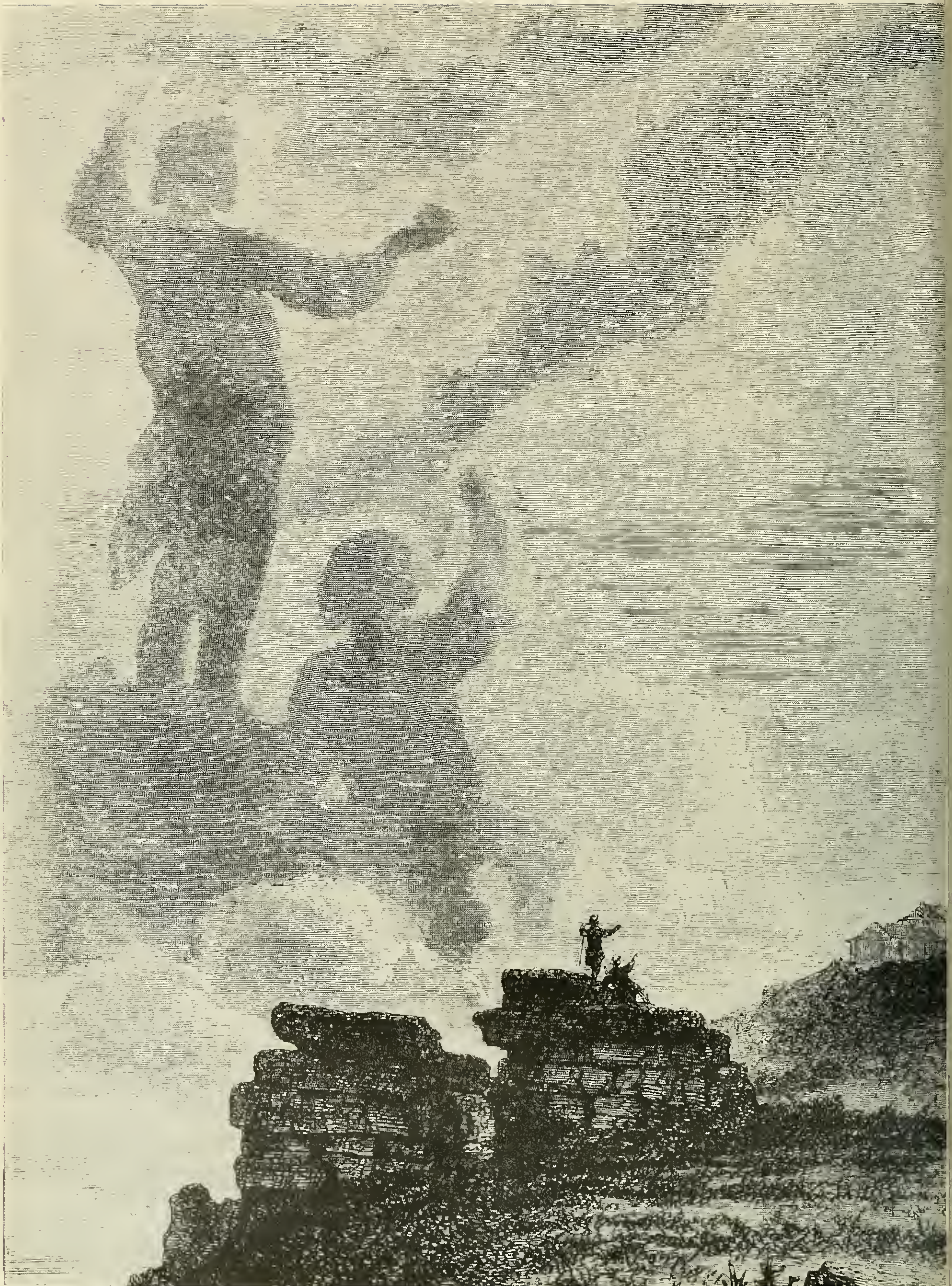
True halos, most frequently observed in the winter, are caused by sunlight or moonlight refracting from ice crystals that float high in the upper atmosphere. Such rings may have a radius—measured along a great circle arc through the sun or moon—of 22° or, less often, 46°, and on rare occasions 90° (the "halo of Hevelius"). The area within the halo appears darker than the surrounding sky, because no visible refraction of light from the ice crystals occurs there.

What are commonly, and wrongly, called halos in an overcast summer sky are usually coronal rings. Coronas are much smaller than true halos—typically they are only 1° to 5° in radius—and are a result of light diffracting from many tiny water drops of uniform size in a thin cloud. They may occur either singly or appear in sets around the sun or moon. This type of coronal ring is not to be confused with the solar corona, the luminous, gaseous envelope associated with the surface of the sun.

MOST often, halos and coronas appear almost colorless. However, both can be colorful sights, especially those seen around the sun. The smaller halos may be vividly red inside, ranging to bluish white toward the outside. The 90° halos have the colors reversed, with blue on the inside. Colored coronas also have the order of the colors reversed. One sort of poorly developed corona, the aureole, ranges in color from an inner bluish white to brown at its outer rim. Rings around the sun are usually less evident than those around the moon, as the sun's brilliance obscures them.



TWO HALOS surround the sun in idealized phenomenon, *left.* Light reflected from vertical ice prisms cause parhelia to appear flanking sun. Old drawing, *above*, shows sun's rays being refracted as they strike upon suspended crystals of ice.



Specter of the Brocken, named after a German mountain peak, occasionally appears in the sky opposite the rising or setting sun. Caused by nearly horizontal projection, i casts human shadows on low-lying mists or nearby mountains

Although it is often not apparent, a alo sky is typically overcast with the hinnest sort of cloud cover—high cirus ("mare's tail"), cirro-stratus, or irro-nebula—in which the ice crysals are suspended. Coronas appear in lower thin cloud cover of suspended vater droplets. Ordinarily, halos and oronas do not appear together in the ky, and certainly not in a single loud, because of the basic difference n the way in which they are formed.

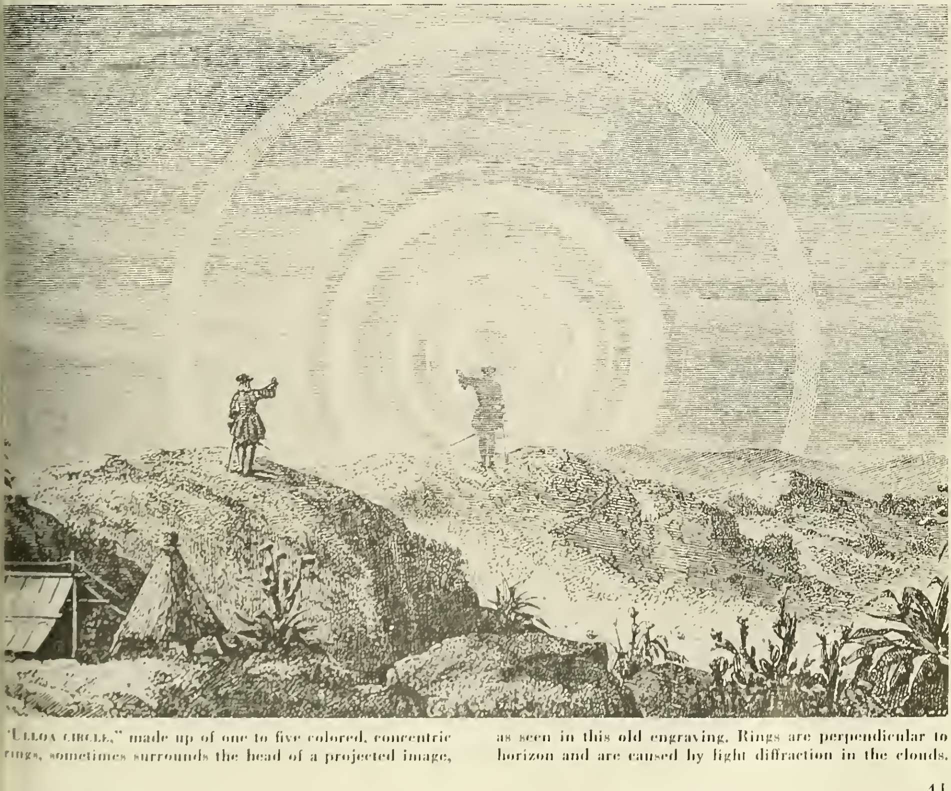
A crude representation of a corona can be attained artificially with imple equipment. To produce such a rojected coronal image, take a sheet f glass upon which a fine cover of lust has been permitted to settle. reathe across the glass to coat it with noisture droplets. Project a concenrated light source through this glass late onto a screen and a colored coona will be clearly visible. The coona also can be seen, without being rojected, by looking at a bright point of light through the glass. Similarly, artificial halos can be produced by coating a sheet of glass with alum crystals, and then looking through the uncoated side toward a light source.

There are a number of variations on simple halos, some of which are extremely spectacular. The "pseudhelion," for example, is visible only from aloft. It appears as a reflection of the sun on the upper surface of a horizontal bank of clouds. Again, at daybreak or dusk, the low-lying sun will occasionally project a person's shadow against a distant cloud bank. This enlarged shadow forms what has been called the "specter of the Brocken." An individual who looks at his projected shadow may see a series of from one to five colored rings around the shadow's head, called collectively the "Ulloa circle." These circles are formed, much like coronas, by the diffraction of light rays in the cloud.

The "halo of Bouguer," a ring of about 38° radius hanging in the sky opposite the sun, is another example. Often called a "white rainbow," because, like a rainbow, it appears in the heavens opposite the sun, it is colorless. This halo is also caused by light reflected from ice crystals that are suspended in the atmosphere.

Pillar halos are strange, vertical shafts of light rising above the horizon at night. Associated with neither the sun nor the moon, these are manifestations of our artificially illuminated civilization. On still nights, when flat snow crystals float in the air parallel to the earth's surface, lights from the ground are reflected back by these flat surfaces, causing the shafts to appear. The beams are white or colored, depending upon the original light source on the earth's surface. Some pillars have been seen that measured over 1,000 feet in height—the height, of course, being related to the intensity of the light source.

Sometimes, right at the horizon, a



"Ulloa circle," made up of one to five colored, concentric rings, sometimes surrounds the head of a projected image, as seen in this old engraving. Rings are perpendicular to horizon and are caused by light diffraction in the clouds.

Dr. Beidleman, Associate Professor of Zoology at Colorado College, has published both popular and technical articles on many subjects, including historical studies of American science.

“mock sun” will appear in vertical contact with the true sun, and occasionally attended by a vertical “sun pillar.” First noted in Danzig by the German astronomer Hevelius on April 10, 1682, this phenomenon has since been explained as a type of mirage, the mock sun being a reflection of the true sun. The sun pillar is a reflection of light from horizontally oriented ice crystals: on some occasions, it may actually appear both above and below the sun at the same time.

During unusual atmospheric conditions, halo patterns may assume strikingly complex proportions. At distances of 22° and 46° from the sun, individual halos may form, each of which may be colored. In addition, at points on these halos above and below the sun, there may be tangential arcs of light. Passing through the true sun, parallel to the horizon, there may appear a white, luminous band or parhelic circle, along which images of the sun are formed. These are known as parhelia but are commonly referred to as sun dogs, mock suns, or, by seafaring men, as “wind galls.”

The most brilliant images occur where the parhelic circle intersects a halo, particularly one at 22°. Mock suns that lie between 90° and 140° from the luminary along the parhelic circle sometimes are visible and are termed paranthelia, while an anthelion occurs as a large luminous body opposite the sun on the parhelic circle, frequently exceeding the true sun in its diameter. Moon dogs or mock moons, known as paraselenae, have also been observed.

Although such magnificent displays are occasionally to be seen above the horizon toward sunset in winter, more often the display is most radiant on a chilly dawn. As the sun rises, the sun dogs move out of their halos and assume a comet-like appearance. By noon, the vision has usually disappeared, leaving the true sun to complete its course alone.

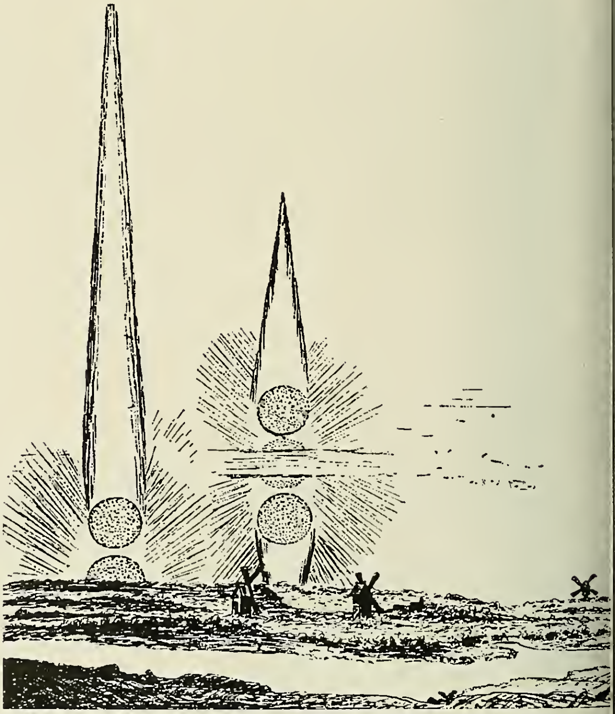
As we have seen, these complex phenomena are associated with the refraction and reflection of light rays from atmospheric ice crystals that have a particular orientation with respect to the earth’s surface. The parhelic circle and ordinary sun dogs are produced by the sun’s rays being bent by the prismatic faces of hexagonal ice crystals that are floating in still air in a *vertical* position. The white parhelic light is reflected; the sun dog lumination is refracted. Sun dogs that lie above and below the real sun, vertical pillars through the sun, and tangential arcs, in turn, are caused by refractions from ice crystals that are *horizontally* oriented.

The brightness and distinctness of the sun dogs depend upon the number and arrangement of the ice crystals in the air. Frequently, the sun dogs may be reddish in color on the side toward the sun and may appear elongated along the parhelic circle. In rare cases, a 22° sun dog may also be surrounded by its own halo, a portion of which passes through or near the image of the sun, itself.

Complex halo displays have never failed to arouse interest and excitement. It is even possible that the ce brated cross that the Emperor Co stantine reportedly saw in the s about A.D. 312 may have been part such a display. A parhelic circle, wi its pillars above and below the su would form such a cross, and it wou appear to be flaming.

The most spectacular halo displ ever recorded was the Petersbu phenomenon, observed by Johann L witz at St. Petersburg on June 2 1790. This display lasted from 7:30 the morning until just after noon, a “had everything”: multiple halos, ta gential arcs, sun dogs, and the colo of the rainbow. Another famous spe tacle often reproduced in drawin was the one seen by Hevelius at Da zig on February 20, 1661, and knov as the Danzig phenomenon.

In the spring of 1912 and the a tumn of 1913, brilliant halo syster were seen by many in Great Brita and the United States. In a letter



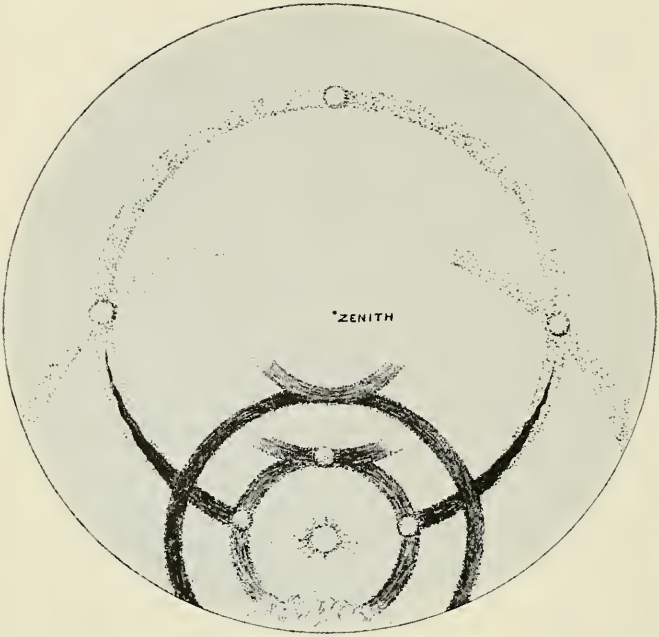
Mock suns in contact with real sun are shown in two stages, and accompanied by sun pillar, in 17th century sketch.

Sun pillar, *right*, sometimes exten above and below real sun, and is lig reflected from horizontal ice crysta

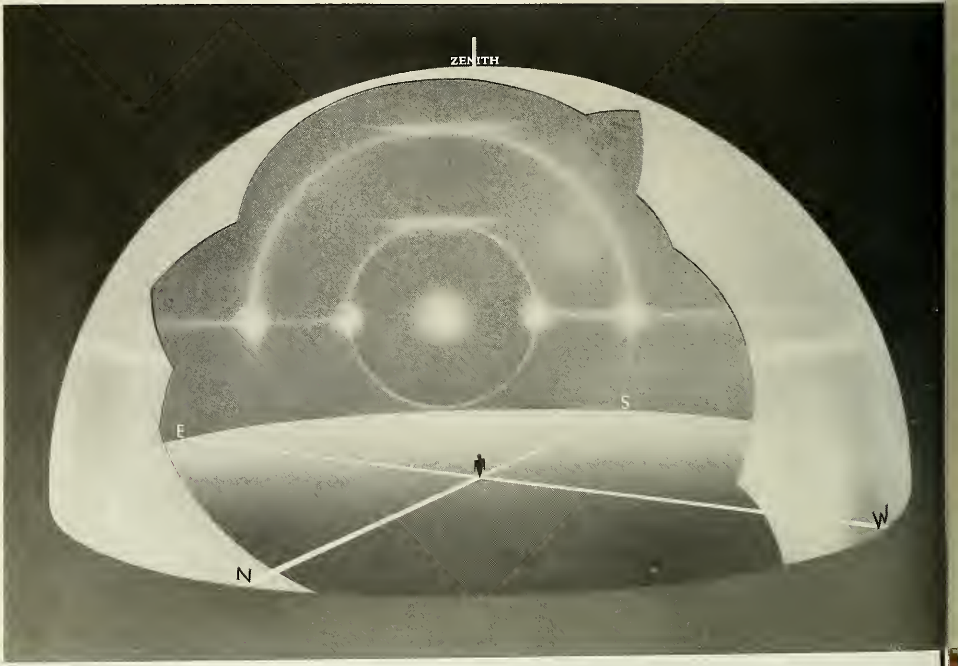
the British journal *Nature*, an c- server wrote descriptively of the sig over Goudhurst on May 17, 191: "The first thing noted was an obje high over the setting sun, just like moustache brushed into a fierce u ward curve. This had a metallic lu- tre like burnished brass, and mark the contact between two coloured ci cles, the top one, of which only abo one-sixteenth was visible, showing tw colors, silvery blue on the conca and rusty buff on the convex. Tl lower halo was complete down to tl horizon, and showed all the colour while from the sun itself a long sle der cone rose about halfway up to tl moustache, and had exactly the san colour and lustre."

OBSERVATIONS in the United Stat during early November, 191 extended from the Mississippi Valle to the mid-Atlantic states, with stri ing displays seen in Missouri, Arka sas, and Virginia. Weather conditio throughout this area were ideal f the displays: a high-pressure syster a thin cover of cirro-stratus, and lac of wind of any strength aloft.

Halos and associated phenomen apparently occur more frequently tha one might guess. The Montsouris Ol servatory in Paris reported 1,317 su or moon halos of 22° in a ten-yea period, or an average of one ever



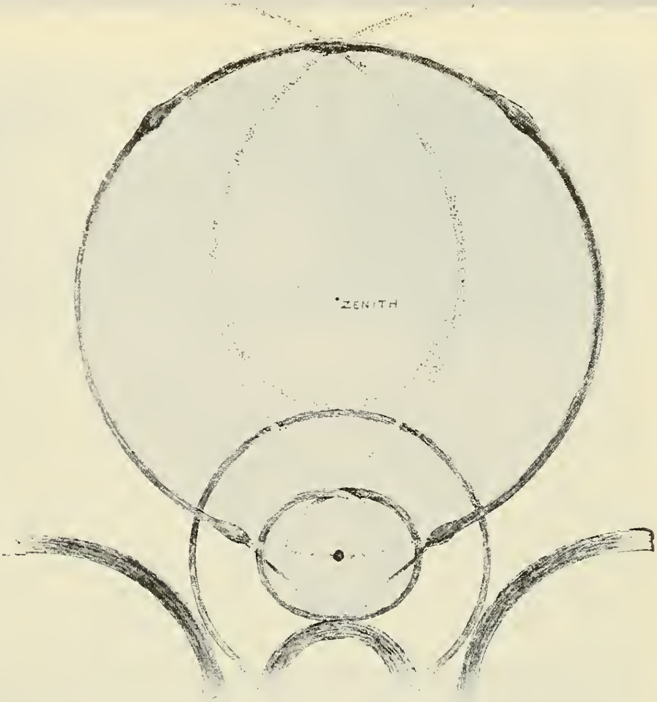
"DANZIG PHENOMENON," *above*, drawn by noted astronomer Hevelius in 1661, is one of best-known recorded displays. Rendition, *below*, shows the main features of a refraction phenomenon, including 22° and 46° halos, "sun dogs" on both halos, two tangential arcs, and a parhelic circle parallel with horizon.



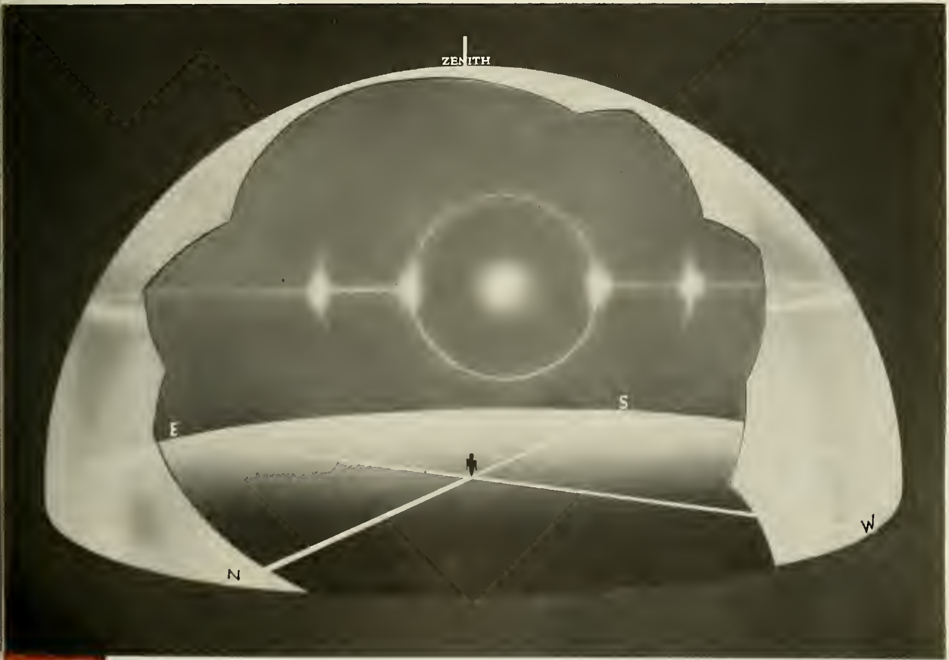
three days, while 46° halos occurred about eight times yearly. Sun halos outnumbered moon halos by about three to one. Sun dogs occurred one day in twelve, on the average, and parhelic circles were observed about once every thirty-three days.

SOLAR halos are most common during the spring in the Northern Hemisphere, with March the most prolific month, and during the late fall in the Southern Hemisphere. Lunar halos, on the other hand, are most often seen in the North during January. Some solar halos have persisted as long as ten hours, but on the average, according to data from the Blue Hill Observatory in Massachusetts, they last about 1.9 hours, while lunar halos last 1.7 hours.

It is understandable that such strange lights in the sky have led people to attribute a prophetic nature to their appearance. One such prophecy frequently has a basis in fact. Clouds that produce coronas often portend precipitation. The adage, "The moon with a circle brings water in his beak," reflects this. A Zuni Indian saying predicts, "When the sun is in his house (corona), it will rain soon." Some of these sayings do not bear close scrutiny, however. "The bigger the ring, the nearer the wet," is actually a misapprehension. A corona will become



"Petersburg phenomenon," ***above,*** **as seen by Lowitz in 1790, was remarkable for multiple halos and vivid colorings. Drawing,** ***below,*** **demonstrates relations of phenomenon to observer at center. Sun is one hour higher than on page opposite, and some of more spectacular features of display have disappeared.**

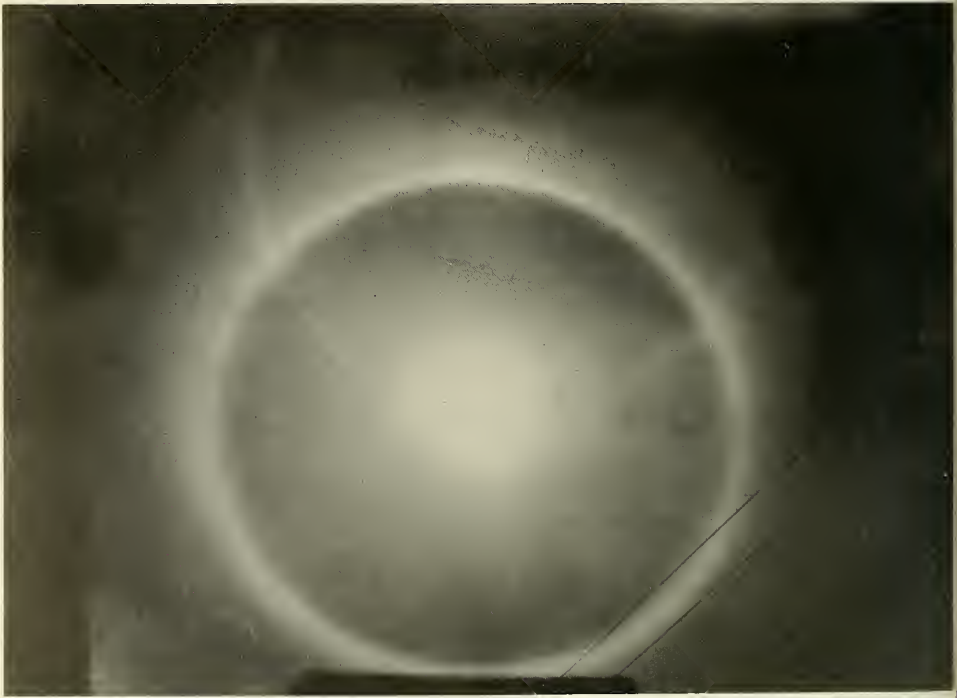


Sunlight refracting from randomly distributed ice prisms causes halos, but if enough ice crystals are oriented at the same angle, other phenomena appear—the type depending on the amount of light and the predominating types of crystals

smaller as rain nears, because the water droplets in the cloud are growing larger at this time and a smaller ring is produced in consequence.

The high cloud cover associated with halos often precedes bad winter weather. A number of studies have been carried out in this field of precipitation prophecy. Data from Columbia, Missouri, gathered early in this century, indicated that precipitation almost always followed a 22° halo in twelve to eighteen hours, and a 46° halo in twenty-four to thirty-six hours. Observations at Blue Hill between 1901 and 1910 indicated that seventy per cent of winter solar halos were followed by precipitation in thirty-one hours.

For more than half a century, the French meteorologist Renou scanned the heavens above his native land, constantly searching for these celestial displays. Yet, so varied are they that Renou, in this long span of time, failed to see one of each kind already recorded. Portentous or merely dramatic, these strange lights in the sky display endless variety. Human beings will continue to watch them—as they did in thirteenth-century England—“. . . for the wonderful novelty of it.”



Sun halo with 22° radius, accompanied by parhelic circle across the sun’s face, was photographed by the U.S. Weather Bureau. The term “halo,” introduced by Aristotle, is now incorrectly used to describe both halos and coronal rings

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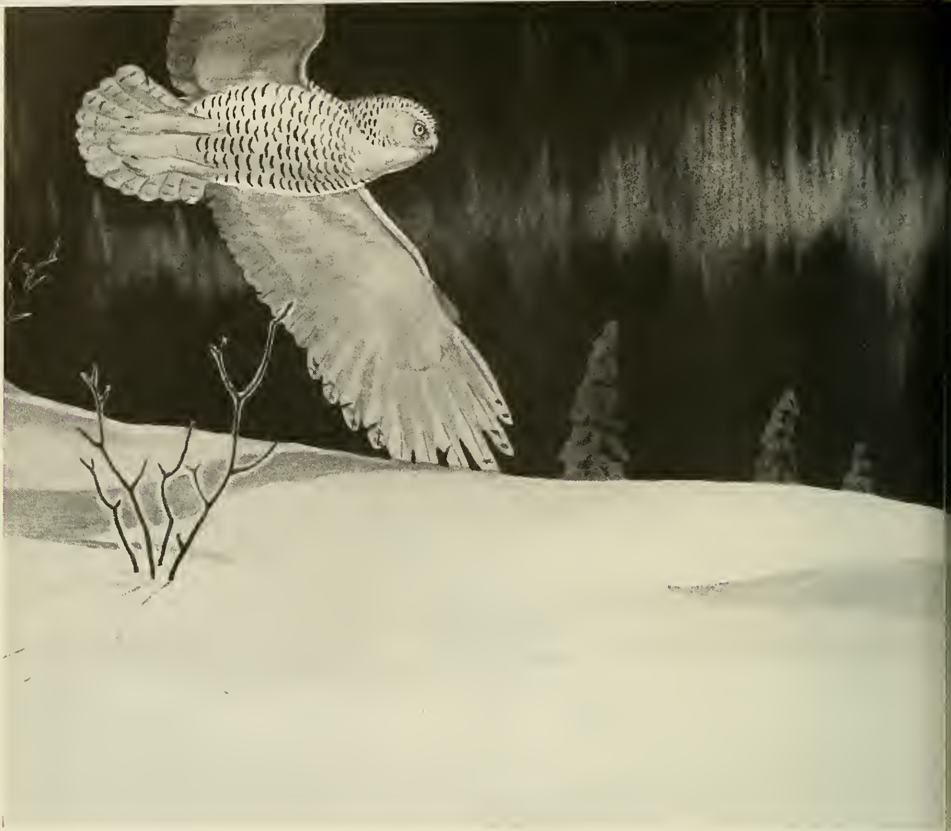


North Woods Winter

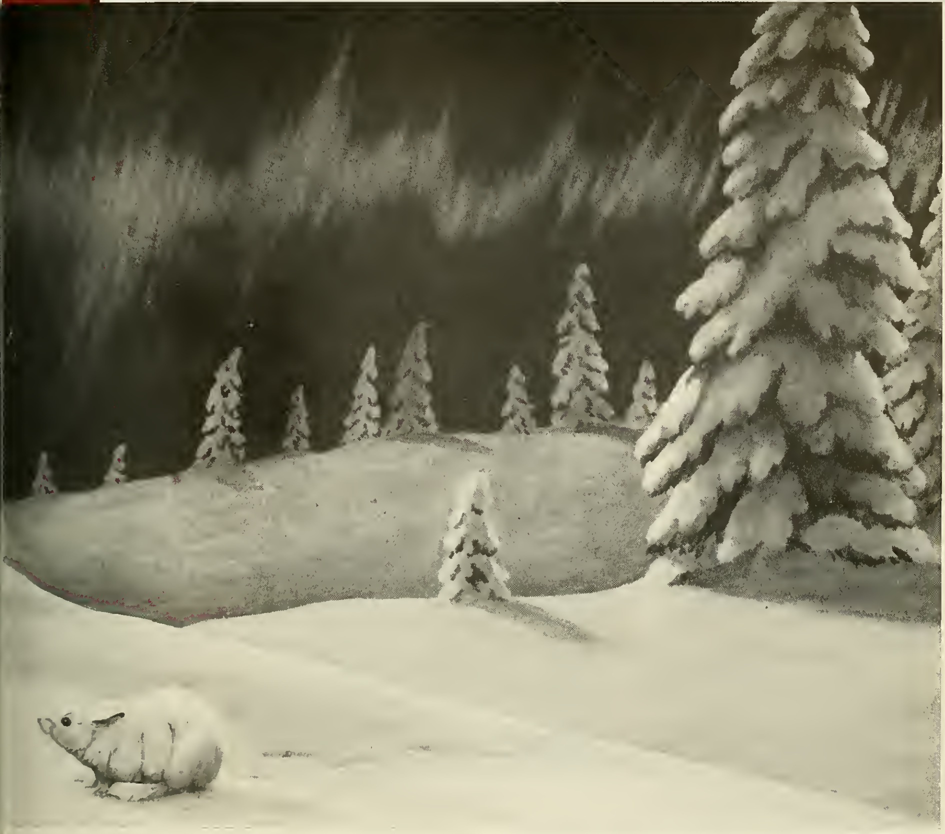
In snowshoe hare country, the Ice Age seems scarcely ende

By Virginia S. Eifert Illustrations by Wayne Trimm

The snowshoe hare made enormous leaps up the trail, veered into the shadows of the sheltering firs, and left behind a series of dot-and-dash footprints across the drifts of snow. By the time I had reached the top of the slope and had come into the balsams where the rabbit had vanished, I could not find it, although its whiteness could have concealed it. I felt certain it was watching as I came toward its domain, and was poised to escape if I continued.

This land of the snowshoe hare is a forest of conifers and aspens that lies in the northern United States and southern Canada. In winter, this forest is a place of deep and abiding snow, with a winter that begins in October and lasts until April, and often until May. For at least five months of the year, the ground is white and the drifts grow deeper with each storm and each day of wind.

The land of the snowshoe hare is glacier country. Here, the effect of the last ice sheet is so apparent that it seems to have left but a little while ago. Geologically, it was only yeste day when the last glacier melte Over the terrain of the Middle Wes the first glaciers of the Pleistocen smoothed everything out, brougl Canadian granite rocks to norther Illinois, scattered deep sand an gravel over Wisconsin and Michiga and filled the landscape with bou ders, which, one by one, farmers sti gather as an annual crop. Ice also d posited a mineral-rich soil over tl prairie states, and left low morai hills where ice, in a bulldozer actio



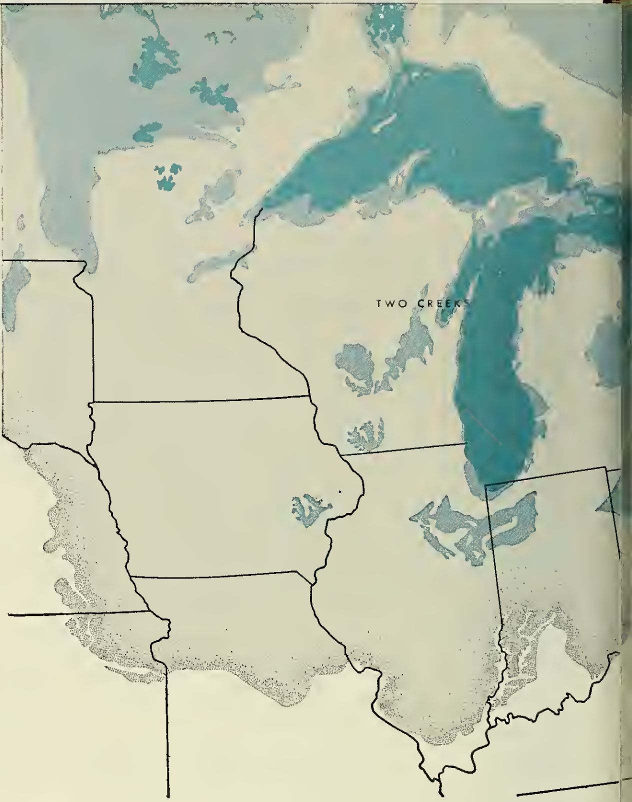
HE SNOWSHOE HARE of the North Woods vitally affects the alance of nature in that cold and snow-covered land. Its abundance insures a food supply for the owls, wolves, foxes, and other animals that must survive in the rigorous climate.

ioved up debris, and then melted. Under the glaciers themselves, all fe perished. This did not happen iddenly, catching everything unware as in an earthquake or volcanic uption. The glacier moved so slowly at its advance could not have shown uch change from one year to anher. Century by century, life contind to exist comfortably just below e great blue-white wall as its unen edges were forever breaking off id forever draining a little water to the south sunshine.

As the ice covered what once were ntinent-wide nesting and feeding ounds, mammals and birds simply ent a little farther south, or else ey perished. The great Pleistocene una—which had occupied all the nd to the Arctic Ocean—was now nfined to a more limited area south the big ice, but this was no special hardship. Mammoths in the marshes had plenty to eat; mastodons fed in the forests; musk oxen grazed on the grasslands; giant ground sloths pulled down tree leaves to eat; six-foot beavers cut poplars and built enormous dams. They dwelt in a green, moist landscape that occupied thousands of square miles below the barrier of ice. Eventually, animals and birds were living much farther south than their ancestors a thousand years before.

THE immovable things, the trees and other plants, eventually were overwhelmed and lost, yet even for rooted vegetation there was time for future generations to escape destruction. As the climate cooled, trees tended to produce more seeds on their sunny south sides. Normally dispersing seeds of northern plants sprouted a little farther south, generation by generation, ahead of the ice. Canadian balsams and spruces eventually were growing in southern Illinois and Missouri, arbutus in Kentucky, partridgeberry in Louisiana. The older generations, back in the path of the ice, were finally knocked down and leveled, as the glacier reached them and passed over their fallen forms, but their progeny flourished in the south.

The coming of the ice was made up of advances and retreats; of lobes of ice pushing out in one direction or receding in another, like a chilly amoeba with constantly shifting shape and direction. Four great ice sheets came over the Middle West, each for a different distance and in a different direction. Between, there was a return to greenery and life far up the thawed continent. Yet, over and over, each warming interglacial interval was ended by another advance of the ice



mass that lurked in the North country.

During the melting times, a braided network of streams, large and small, drained this vast quantity of water down the continent, funneled it into the Wisconsin, the Illinois, the Ohio and the Mississippi rivers. Before the Ice Age, there had been no Great Lakes. Where they lie today—the result of the great, final melting—there were formerly old river valleys, much eroded, then widened, gouged out, and deepened by the action of the glaciers and by their inconceivably great weight. When the ice finally melted, these old valleys were filled with water, which spilled out on all sides to form bodies of water much greater than any there today.

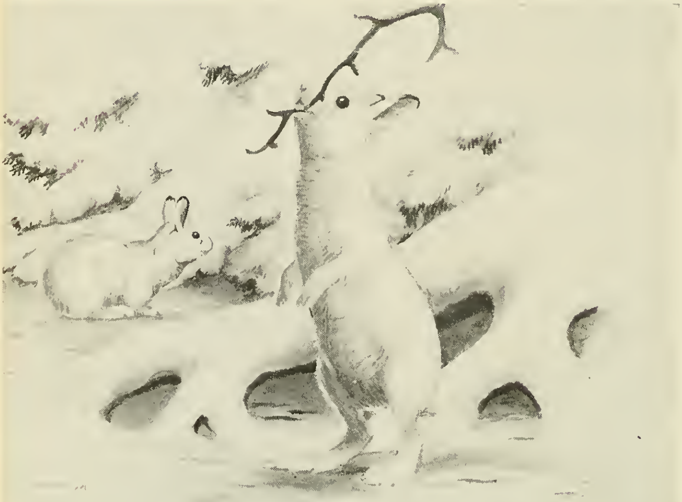
LAKE Algonquin then occupied, in the main, the position filled by Lake Michigan now, but it was very much broader. Lake Agassiz extended the present boundary of Lake Superior far into Saskatchewan and Manitoba, and was larger in area than all the other Great Lakes combined.

About 24,000 years ago, ice of the Wisconsin Glacier covered what was soon to become the Great Lakes, but did not extend very far below their southern extremities. Six thousand years later, the ice had gained strength and had pushed determinedly in its final surge south, almost to tl Ohio River and the hills of Cincinnat

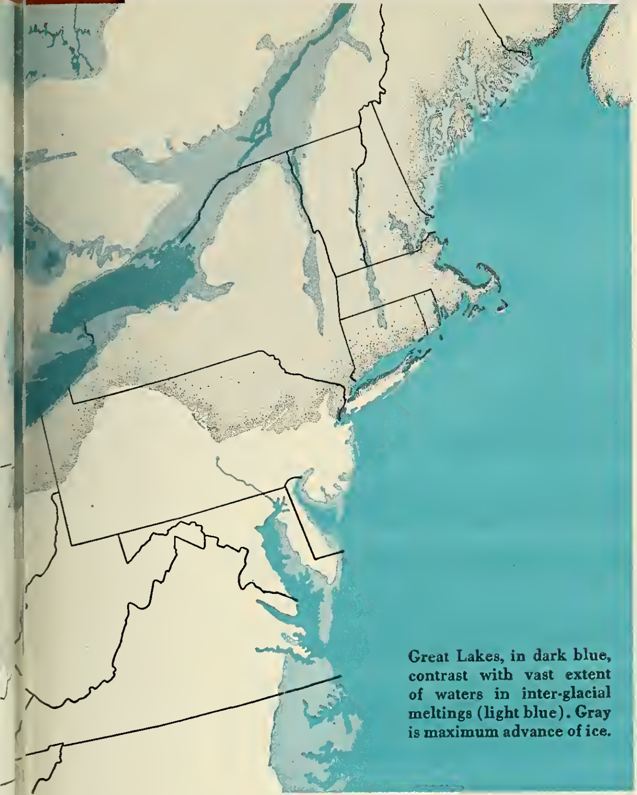
THEN the ice set about a prodigiou melting that lasted for five tho sand years, retreating until half Lake Michigan was open. A thousar years later, when the lake was free ice, the glacier advanced again.

Meanwhile, a spruce swamp had chance to develop in the shallo lakes and marshes formed by me water in southeastern Wisconsin. the ice began its final assault, tl floods preceding it drowned the spruces. When the ice finally reach the dead trees, it passed ponderous over them, knocking them all fl and pointing in the direction towa which the ice was heading.

Mud and glacial rubble were d posited thickly on top of the fall spruces, burying their remains. Tl remnants of this forest were hidd until geologists discovered them ne Two Creeks, Wisconsin. Their pre ence gave the name "Two Creeks I terval" to that last erratic push of i



DURING days of deepest freezing, the hare turns to woody plants for its food, stretching up to nibble at aspens, or to peel bark from young maples or pines.



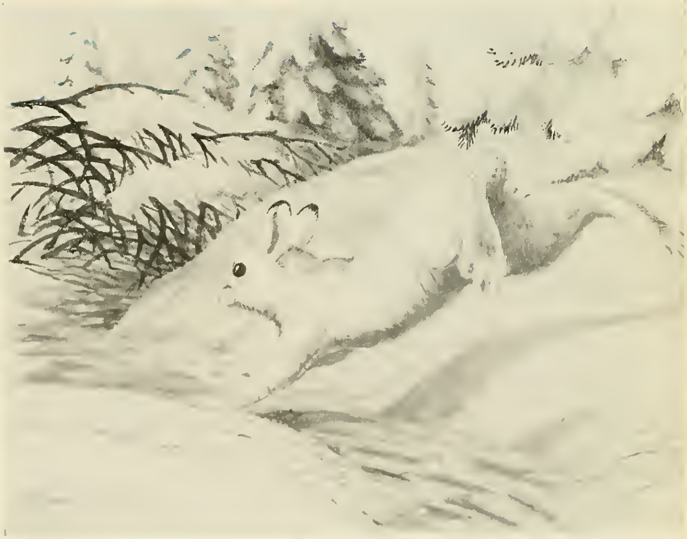
Great Lakes, in dark blue, contrast with vast extent of waters in inter-glacial meltings (light blue). Gray is maximum advance of ice.

nd gave it, moreover, an exact date. arbon 14 dating revealed that those ruces were living 11.300 (±300) ars ago. This is considerably more cent than anyone had thought that e ice had last come south. The ruces at Two Creeks pushed forard the time scale of the Pleistone's end by thousands of years. Been seven and eight thousand years o, the ice left the Great Lakes coun- and has not yet come back.

N the wake of this last glacier, thousands of small lakes were left in llows in Wisconsin. Ontario. Minsota. Michigan. northern Illinois, d Indiana. Wherever ice had lain elting in a depression. a lake or nd formed. Some of these meltols drained quite away. but thounds remained. particularly in the orth Woods. The drowned, maned. curried. wet. lake-strewn sand d gravel of the post-glacial landape was again ready for the return living things. ready to become the nd of the snowshoe hare.

The landscape, today, is accented by the dark spires of spruce. balsam, and cedar. The broad crowns of the pines stand above all other trees. and the white-on-white of birches, with their black scars and russet twigs, are part of the North Woods picture. Although it is largely a white world, its appearance is varied endlessly with the blueness of shadows on a north slope; by the rainbow sparkle of snowflakes dislodged from pine twigs and cascading through the sunshine; by the winter colors, which range from the purple-brown of the alders to the scarlet of basswood buds, the beige of hazel catkins. and the deep rose of the red pines' bark. In spite of miles of whiteness, it is a colorful land, a land that is full of life.

FROM the signs all about me, animals and birds appeared to be doing very well. Long since. the weak had perished: late winter contains only the strong and healthy. Everywhere I found their tracks. and most abundant of all in this hilly balsam country were the rabbit highways—lying above frozen bogs and lakes, climbing the hills, dissecting the balsam thickets. So many hares had come along that their chubby tracks had beaten broad lanes through the soft snow. The animals had stood on



SOMETIMES a hare can reach a speed of thirty miles an hour during short spurts, planting the great hind feet ahead of the forefeet to add momentum.

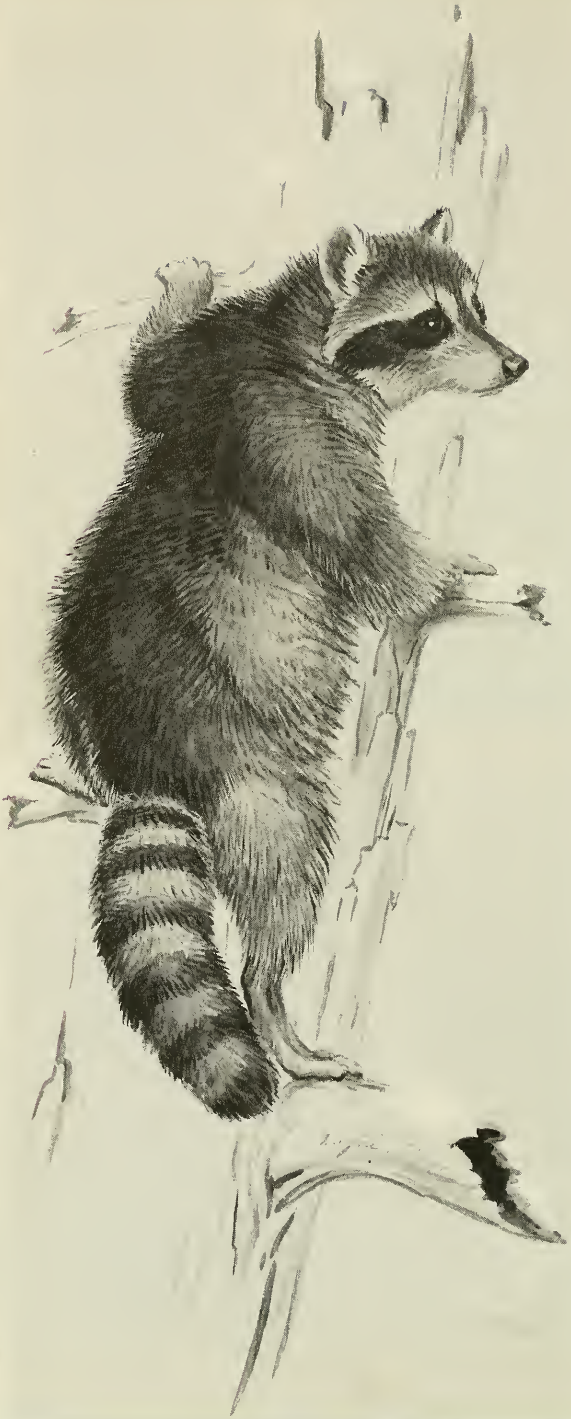
tiptoe, stood as high as they cou reach to peel off the tender bark young red maples and pines; aspe had been nibbled: even the lavende colored canes of the wild raspberri in the old lumber clearings had bee pruned by hares' teeth.

To get about more easily on th snow—and getting about with spee and efficiency can mean the differen between life and death to the hares they find it practical to travel whe others have gone before. The lan assure them of a packed-down rou that always leads into some thicket tangled hideaway, in case danger pu sues. The individualist, taking life hand (and sometimes losing it) ma also skip gaily over the frozen lak through forest and over open bo leaving sharp, staccato tracks.

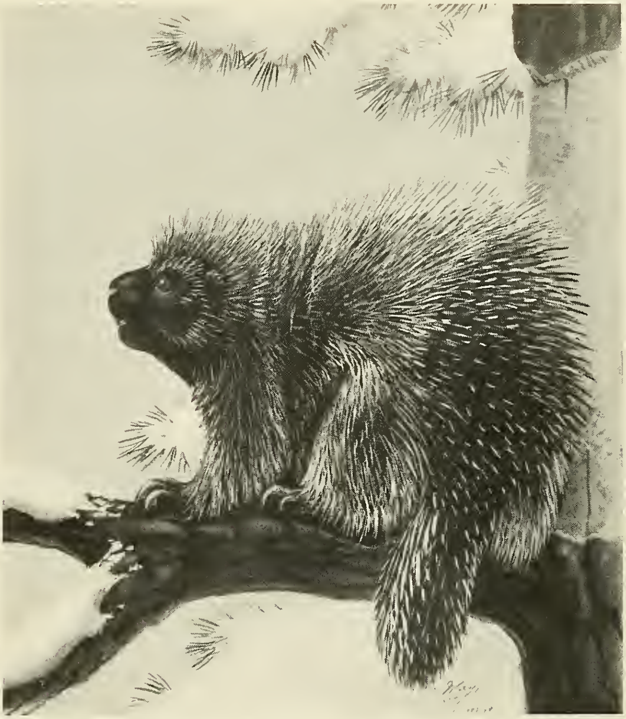
Such tracks appear to be going the direction opposite that whi the rabbit really took. In his hurr the animal puts down his two lar hind feet in front of the smaller for feet. By the time the snow is a day two old, however, the majority of th tracks are all but indistinguishable the maze of rabbit lanes crisscrossin the balsam country. The big sno shoe hare that had led me, on my ov snowshoes, up the hill to the gre dark-green balsams, had followe one of the main routes; the trail ha led it to the concealment of the tree

Then suddenly, from a few yar away, where it had been sitting such quietude that it had become pa of the snow, a big white hare with sooty nose and ear tips burst aw and leaped in great bounds across th snow. Startled, careless of followin the lanes, it was Alice's White Rabb recklessly bound for an unknown a pointment, rashly printing large, we punched, widely spaced tracks f anyone or anything to follow.

The animal went off at a curve a was quickly out of sight. Hares ha been known to speed away at thir miles an hour, yet they seldom r for very long in a straight line. Th may follow a curve, making a lar circle, and come back to their balsa thickets again. Counting on this. waited in the shelter of the firs, whe chickadees chittered in cheerful d regard for the zero cold.



Raccoon backs down from hollow tr nest to forage in snow for anything can find—from scraps of meat to bu



Porcupine takes up position in tree and eats twigs, buds, needles, or bark in large radius around its perch. When diet palls, it moves to another tree.

istening to the chickadees, I could
thought winter was a simple
g in this land, but I knew better.
y creatures cannot exist in this
ronment. In a ruthless economy
election, the animals active in win-
are reduced to those able to find
l and withstand cold.

erhaps three-fourths of the birds
d in the North Woods in June
rate in winter far to the south—
e as far as Mexico, Central and
th America. Adult insects largely
sh, although their eggs, larvae, co-
s, fastened on twig, dead leaf, or
, still remain, neat capsules of
inuity. Of the mammals, only the
migrate. Skunks and woodchucks
r a state of hibernation that low-
the metabolism, slows breathing,
tbeat, and body functions, and
ices the need for food until spring
gs new supplies.

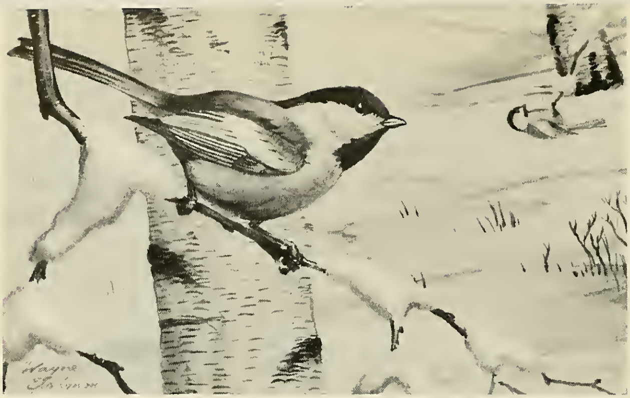
ut rabbits, mice, squirrels, and
are active all winter long. They
and run and race. The smaller
are prey for the all-winter hunt-
the hungry ones—foxes, wolves,
ws, and weasels. The deer try to
enough greenery and tender
vse on the cedar trees in the
mps to stave off starvation.

ILL other mammals are adapta-
ble. With a comfortable adjust-
t to winter, raccoons, chipmunks,
krats, and beavers find it possible
eep without requiring much food,
etimes for days at a time. The
munk dozes on top of a food sup-
in his den; he seldom needs to
e his bed for a bite to eat. The
krats and beavers go down the
el slides below their huts, to the
ozen lake bottom for a lily root
lam, or an aspen log put there
winter gnawing. The fat, deeply
ed raccoons, upon awakening
ry in a hollow tree—the females
immatures together, the males
here—back down the trunk and
ge across the snow. Anything will
or them—frozen scraps left from
fox's meal, some small creature,
n time of real scarcity, birch and
wood buds, and even cocoons.

he porcupines are neither very ac-
nor are they the sort to while
y the winter in a den. They get
t rather awkwardly in the snow,
ing a deep, plodding trail show-
the drag-marks of the tail, but
do so in order to get from one
to another. That day I had come upon a large black porcupine propped in the crotch of a white pine, frost on its quills and a "here I stay" look in the witless, shoe-button eyes. It must have been up there for at least a week, for it had eaten a large gap in the pine twigs and needles and appeared to be contented with both the seat in the crotch and the supply of tender bark and greenery all about. It had only to move to another spot in the same tree to find a fresh dinner.

The large carnivorous animals and birds are the ones that have the grimmest and most urgent winter battle to find enough to eat. In a land as cold and snow-covered as this, it seems impossible that there should be enough to go round. But it is the snowshoe hare, the abundant white rabbit of the North, that provides the answer, the supply that keeps starvation away. In maintaining a balance in the wildlife of the North country, the hare is the single creature affecting it the most. Long ago, the hare often kept Indian villages alive with meat and warm with soft furs in the hardest of winters; and it fed wolves and foxes, lynxes, and cougars, fed owls and coyotes, martens and wolverines, in the same way it does today.

Yet the hare has a defense, a protection that is perhaps of greater value than would be claws or sharp teeth. Each autumn, white hairs come into the brown coat. The brown falls out and, in about ten weeks, the hare has become pure white. At the same time, if the season is normal, snows have transformed the North into a world of white. Now the hare is a ghost, hidden in full view against the snow. When the winter sun is bright, the hare's shadow, dark upon the drifts, is more conspicuous than the animal itself. This is a dangerous, telltale image, and the hare appears to avoid its implications by spending its days largely in woods and thickets, in the safety of the shadows.



Chickadees, sharply black and white against the birch and firs, can always find seeds or buds on which they feed with apparent unconcern for zero cold.

I looked at my watch. The hare that had departed from the balsams in such a hurry had been gone for eight minutes. If it was going to return in the circular route it was supposed to take, it ought to be back soon. The air was very cold, even in the shelter of the trees. As I was about to give up my vigil, a shadowy ghost came clipping in from behind me.

The hare was so little visible against the whiteness that I had to know it was there before I could assure myself that it had indeed come back. I moved. The hare moved. I could see it plainly now, alert ears tipped with black, a smudge of black around nose and face, eyes dark and alarmed, the rest of the body fluffy and white, almost like an Angora rabbit. I moved my hand, and the rabbit cut out in a big circle again. It would get back again to its thicket, no doubt, but I would be elsewhere.

As I moved away, crunching a trail with my own snowshoes on the drifts, I came upon tracks that a frantic, fleeing snowshoe hare had made. The animal had left the rabbit highways and its tracks were curiously alone and stark in their accurate punching of the broad-spaced signature. But in the deep snow before me lay other tracks, large, purposeful, doglike; leaps that encompassed the trail in magnificent, nine-foot bounds. Wolf tracks.

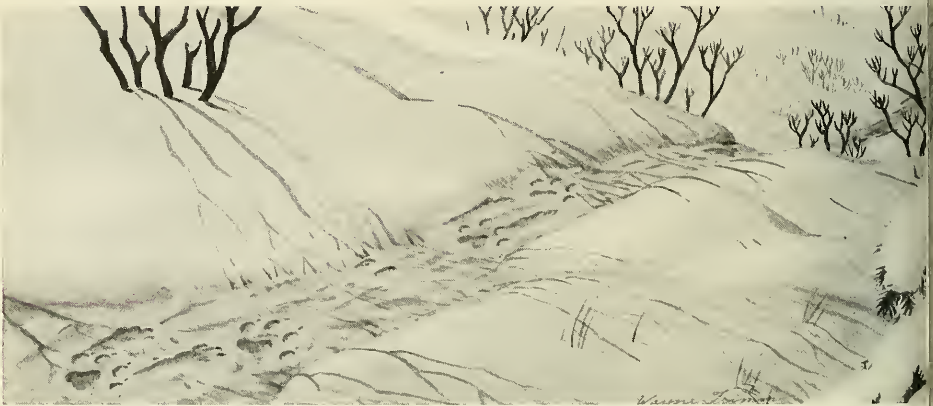
I felt suddenly alien to these woods. Something else was here, some other presence. I saw nothing, but the tracks were there, and they were fresh, loose snow kicked up around them.

I followed them for a little distance through the openness of the pines until, suddenly, still other tracks lay imprinted. It was the first time in snowshoed wanderings here tha had come upon any snowshoe tra other than my own and the rabb These were different, the round b paw rackets that trappers in the b country sometimes wear. The l paws fell in with the wolf tracks, tially obliterating them.

Mrs. Eifert's *Land of the Snowsh Hare*, from which this is an excer was recently published by Dodd, Me and Co. (Copyright © 1960 by Virgin S. Eifert). Wayne Trimm is a we known portrayer of nature subject

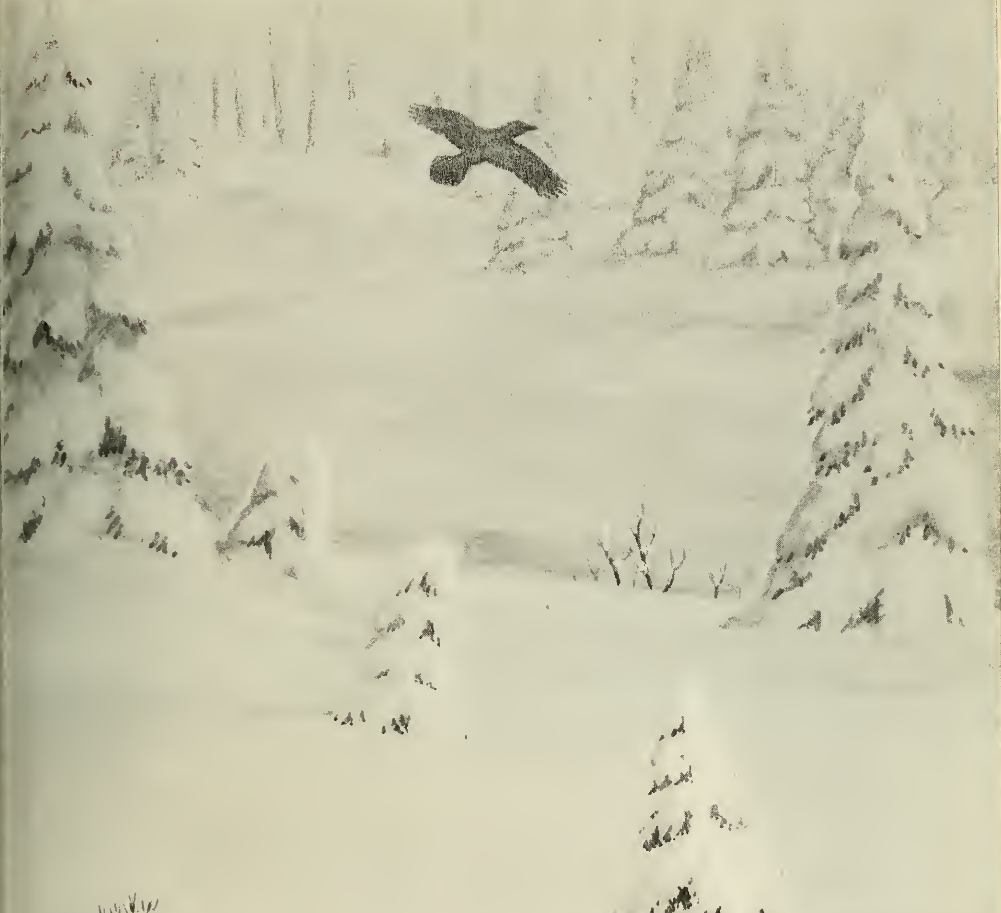
I was aware then of a furious, bi coldness in the air, a chill struck inside my inner warmth. wolf and the hunter and the sn shoe hare: let them be. A low bank of clouds had risen and now westering sun had gone under t blanketing. No wonder the air now so cold. A great silence cl down and the gloom of the clouds like a gray cloak upon the fores turned, then, and, still with that se of being watched, hurried thro the deepening cold toward the warr food, and friendliness of my cabi

By the time I reached the d snowflakes were coming down h ily. Their veiling blurred the dis spruces, screened the far asp Dimly at the top of the slope w the aspens began, I could see a g shape move into the woods. Thro the rushing flakes a raven flap one wing feather missing, toward distant shelter of the snow-clad pi

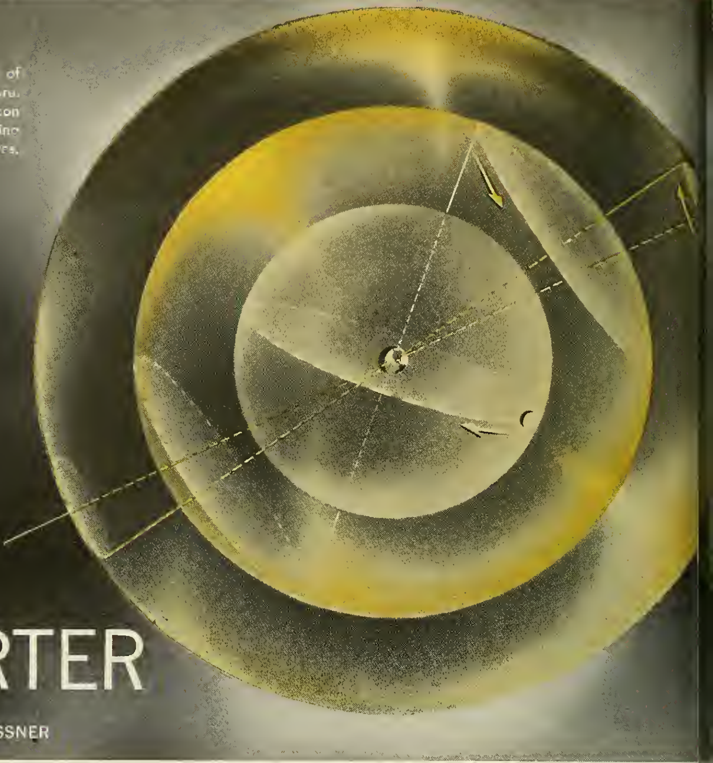


Tracks of the fleeing snowshoe hare are interspersed with grim reminders of savage nature—large, doglike tracks imprinted in snow by a pursuing wolf.

Raven, *right*, stark against the whit the landscape, flies to pines for she



Ideal case of Eudoxus' theory of homocentric spheres is shown here. Apparent motions of sun and moon were explained by counterrotating system of three attached spheres.



SKY REPORTER

By Simone Daro Gossner

The first known attempt to explain the apparent motion of celestial bodies in scientific terms is to be found in Greece, in the fifth century B.C. For several centuries before that time, the Babylonians had accumulated a vast quantity of astronomical observations and had devised some methods whereby they could predict the positions of planets; they left us many tablets outlining their procedure, but we have as yet no record of the theory on which these precepts were based.

The first gropings of Greek philosopher-scientists are poorly known, too, because their original writings were destroyed and gained diffusion only through quotations in historical and scientific works of a later epoch. For that reason, it is not possible to trace the influence of Babylonian thought on early Greek astronomy. In fact, one cannot even say when the first rational cosmology began to take shape. In the fifth century, the disciples of Pythagoras already confront us with a mature system.

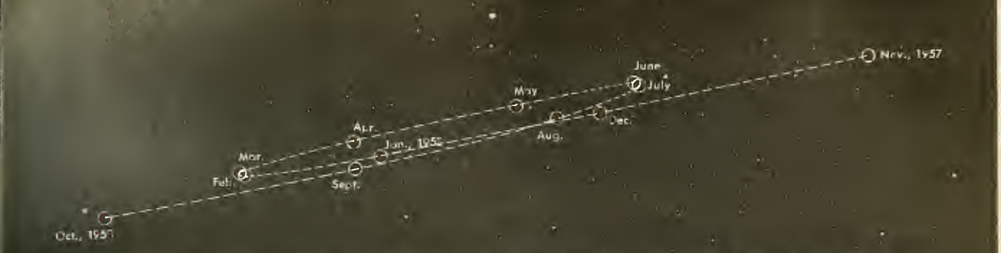
The Pythagoreans held that the earth is a sphere—whereas Thales, a scant hundred years earlier, still believed it to be a disk afloat on the ocean. They also thought that all celestial motions are circular, geocentric, and of constant speed. History does not say by what reasoning they had come to that conclusion, but it may have been nothing more than an expression of their conviction that the sphere and the circle, being perfect shapes, were the only figures worthy of representing the heavens.

Philolaus of Croton, who owed much to the Pythagorean heritage, discarded their view that the earth is the center of the universe, but retained the notion of circ ar orbits (a notion that would endure until the days of K pler). He assumed that all the known "errant" bodies— ne sun, the moon, Mercury, Venus, Mars, Jupiter, and Sat n —revolved around a central fire. As he explained it, ne fire could not be seen from Greece, because that side of ne earth was always turned away from it, and, furtherm e, there was an *anti-earth* in the direction of the antipo s, which forever shielded the earth from the fire's heat.

Unfortunately, the idea of a moving earth was too ntrary to common-sense experience to be readily accep d. Philolaus had few followers, and the earth remai d firmly static in the theories of the next two thousand ye s.

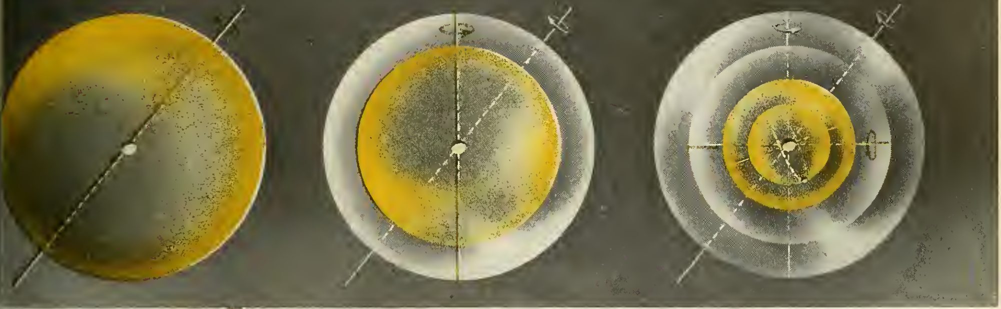
In the fourth century B.C., the standard-bearer of G k cosmology was without a doubt Eudoxus of Cnidos, ho has been called the founder of scientific astrono y. Whereas Philolaus' system accounted only in the most neral terms for the apparent motions of celestial bodies, ne theory of Eudoxus was a complex mathematical attem to explain these motions in minute detail.

No one could have been better prepared for the t k. Born in Cnidos, *ca.* 408 B.C., Eudoxus studied ge netry and medicine, and became a pupil of Plato at the ge of twenty-three. After learning Pythagorean astronom at the newly founded Academy, he traveled to Egypt w re he remained for sixteen months. There he found the pportunity to supplement by his own observations (a n observatory near Heliopolis) the already extensive m e-



oops" in apparent motions of planets against the background of fixed stars—such as the example of Jupiter, *above*—needed a total of four homocentric spheres to be understandable in terms of Eudoxus' theory. Here, Jupiter's motion is seen for one year.

st, or outermost sphere in Eudoxus' scheme, *below*, served to ccount for diurnal motion from east to west. The second, linked to first, explained planet's motion along the zodiac. Finally, he proposed third and fourth spheres, with planet attached to latter.



al that he secured from Egyptian astronomers. Thus quipped, he was able to draw on the full resources of his ieoretical training for the analysis of his observations.

The geometric interpretation of celestial motions deised by Eudoxus is called the *theory of homocentric heres.* Its avowed purpose was to "preserve the phenomna," that is, to account for all the peculiarities in the aparent paths of celestial bodies, and particularly for the loops" in the sidereal motion of planets (*see* diagram).

UDOXUS retained the Pythagorean principles of a static earth and of uniformly circular celestial motions. ince, however, the apparent orbits of planets depart apreciably from a circle, he attempted to explain these vaaries as *combinations* of circular motions. In an ideal case at left in diagram, *above*), the combination is accomlished as follows: let the observed body be attached to ie equator of a sphere centered on the earth and rotating t a given constant speed. If no other sphere is introduced, ie body merely appears to move in a circle around the arth. If however, the extremities of the axis of rotation of iis first sphere are attached to a second, larger one, also entered on the earth and rotating at constant speed, the iovement of the inner sphere becomes a wobble and the iotion of the body is similarly affected. This motion can e modified further by attaching the axis of rotation of the econd sphere to still a third one, and the same procedure iay be continued until the apparent path of the body is ully reconstructed. It need hardly be added that the speeds of rotation and mutual inclinations of the axes must be chosen with care to achieve the purpose.

Since the most complex gyration is that of the innermost sphere, it is easy to understand that the various components of a body's motion are accounted for, in order of increasing complexity, from the outermost sphere inward (at right in diagram.) For each of the five planets (Mercury, Venus, Mars, Jupiter, and Saturn), Eudoxus found it necessary to use four such spheres: the outer one for the diurnal east–west motion; the second for the orbital motion eastward along the zodiac; the third and fourth combined—that is, the two inner ones—for certain changes of latitude and for the loops in the planet's apparent path. Three spheres each sufficed for the sun and moon, since there were no loops to be accounted for, while one sphere served for the stars, which exhibit only the diurnal motion.

Within the accuracy of observation available in his day, Eudoxus' theory gave a satisfactory account of the apparent motion of all the bodies considered, with the possible exception of Mars. This planet's orbit, being somewhat more elliptical than those of Jupiter and Saturn, lent itself less readily to a description in terms of circular motions. Eudoxus' system of homocentric spheres gained wide acceptance. In the ensuing centuries, his original system was modified gradually by the introduction of additional spheres, to keep pace with new data produced by the increasing accuracy of observations. It was adopted by Aristotle without essential alterations and was superseded only by the theories of Hipparchus in the second century B.C.

THE SKY IN FEBRUARY

From the Almanac:

Last Quarter	February 8, 11:50 A.M., EST
New Moon	February 15, 3:11 A.M.. EST
First Quarter	February 22, 3:35 A.M., EST

For the visual observer:

Mercury will be most favorable for observation at the beginning of February, reaching its greatest eastern elongation on February 6. Low in the southwest in the evening sky, it will set one and a half hours after the sun on February 1, and one and a quarter hours after the sun on February 15. The planet will be at inferior conjunction on February 21 (EST) and will remain too close to the sun to be seen in the latter part of that month.

Venus, in Pisces, will be very brilliant (—4.2 magnitude) in the evening sky. Throughout the month it will be high above the southwestern horizon at dusk and will set four hours after sunset on February 1, and three and a half hours after sunset on February 28.

Mars, in Gemini, will fade gradually from —0.5 magnitude on February 1 to +0.3 on February 28, as it continues to recede from the earth. It will be found high in the southeast in the early evening sky and will remain visible most of the night. It will set two hours before sunrise on February 1, three hours before sunrise on February 28.

Jupiter (—1.5 magnitude) and Saturn (+0.8 magnitude) will form a close pair in Sagittarius in the morning sky. They will rise approximately one hour before sunrise on February 1, one and a half hours before on February 15, and two hours before on February 28. At the beginning of the month, Jupiter will be about two degrees west of Saturn. It will pass two tenths of one degree south of Saturn on February 18, and will be one degree east of Saturn at the end of the month. These planets may be distinguished readily by noting that Jupiter is the brighter.

Total solar eclipse:

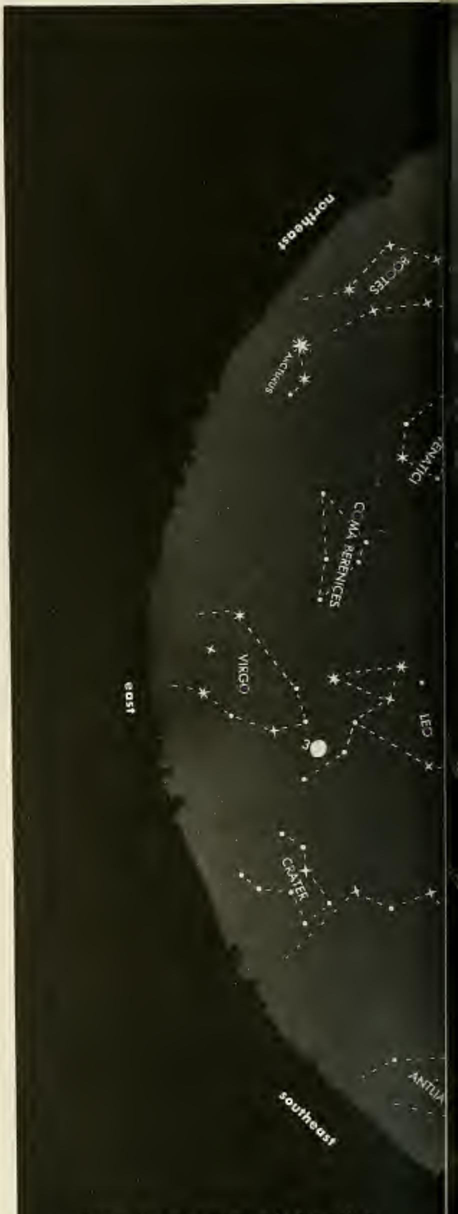
A total eclipse of the sun will occur on February 15. Although it will not be visible in the Western Hemisphere, it deserves mention in view of the fact that the track of totality, as well as the zone of partial phase, will lie almost entirely over land. This does not happen very often because oceans account for approximately four-fifths of the earth's surface. Any extended surface area such as that covered by a solar eclipse, therefore, is likely to include a substantial percentage of water.

The path of totality will begin at sunrise in the Atlantic Ocean, off the coast of France. It will then proceed across southern France, northern Italy, the Balkans, and the Crimea, and will then curve in a northeasterly direction across Russia, to end at sunset in northern Siberia.

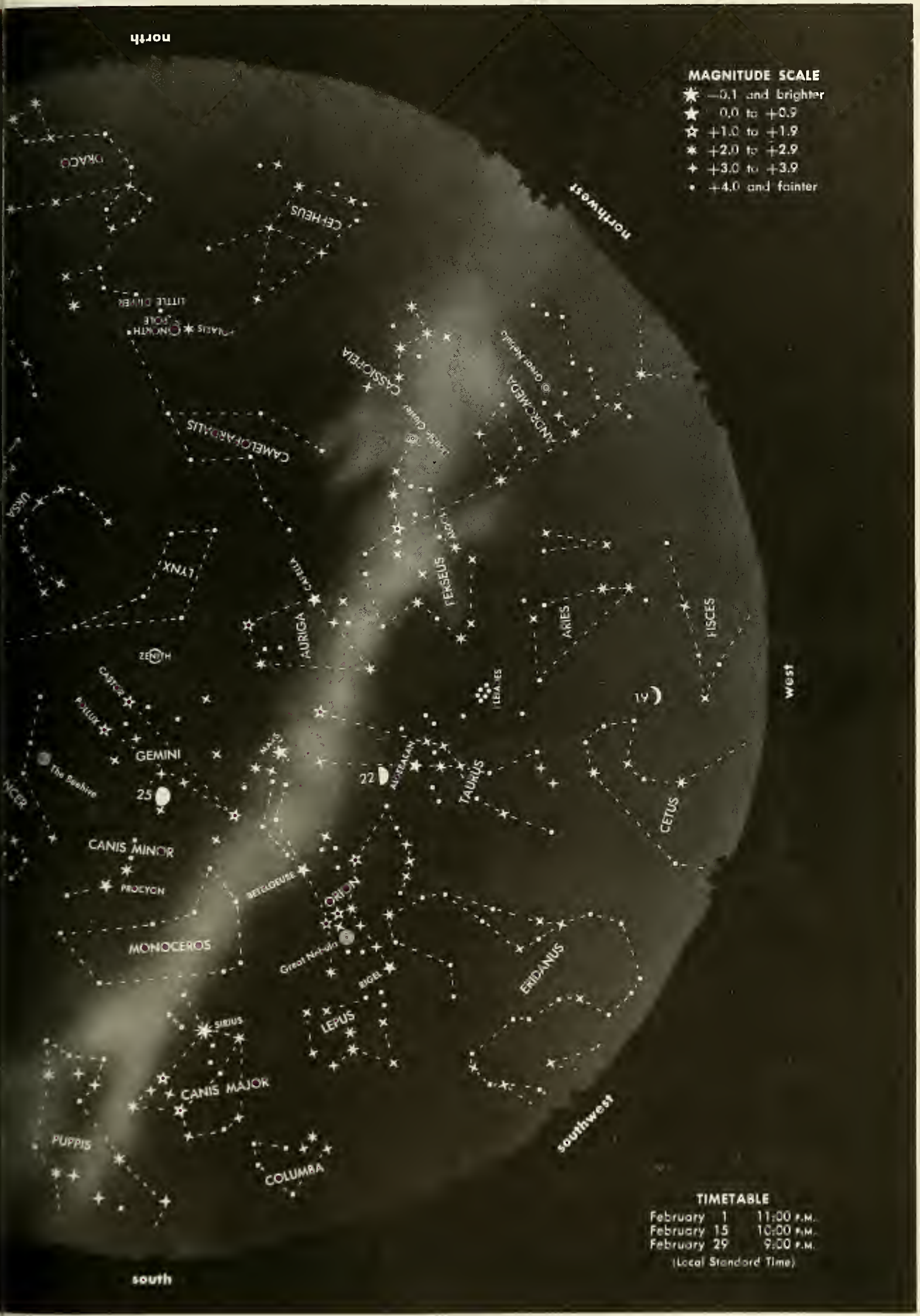
Partial phases will be seen in all of Europe, in the part of Africa that lies north of the Equator, in the Arabian Peninsula, and in most of Asia. The longest duration of the partial eclipse will be slightly over two hours and forty minutes, north of the Persian Gulf.

The outlook for scientific observations of the total phase is rather poor. European weather leaves much to be desired in February, and the altitude of the sun in the region of totality will not exceed 28 degrees.

On the preceding pages, MRS. GOSSNER offers the second in her 1961 series on the growth of cosmological concepts.



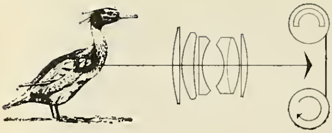
To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.


north
MAGNITUDE SCALE
★ −0.1 and brighter
★ 0.0 to +0.9
☆ +1.0 to +1.9
✱ +2.0 to +2.9
✦ +3.0 to +3.9
• +4.0 and fainter
DRACO
CEPHEUS
LITTLE DIPPER
NORTH POLE
POLARIS
northwest
CASSIOPEIA
Great Nebula
ANDROMEDA
CAMELOPARDALIS
Double Cluster
URSA
LYNX
ALGOL
PERSEUS
CAPELLA
AURIGA
ARIES
PISCES
ZENITH
PLEIADES
19
west
CASTOR
POLLUX
GEMINI
MARS
The Beehive
NCER
25
22
ALDEBARAN
TAURUS
CETUS
CANIS MINOR
PROCYON
BETELGEUSE
ORION
MONOCEROS
Great Nebula
RIGEL
ERIDANUS
LEPUS
SIRIUS
CANIS MAJOR
southwest
PUPPIS
COLUMBA
south

TIMETABLE

February 1	11:00 P.M.
February 15	10:00 P.M.
February 29	9:00 P.M.

(Local Standard Time)



NATURE and the CAMER

Frigid weather poses picture problem

By David Linton

WINTER OFFERS unique opportunities for nature photographs, but it brings a number of perplexing problems, too. Since I have had considerable experience taking pictures in the Arctic, people often ask me how I manage to work at such low temperatures. Actually, keeping the photographer in working order is a minor problem compared to keeping the cameras and film working.

It is possible to design equipment that will function well in any specified environment but, unfortunately, most of us have to work with cameras, film, and accessories that are designed for normal temperature and humidity. Even in the Temperate zones, it gets cold enough in winter to make most cameras unreliable, if not completely inoperative.

There is a certain amount of lubrication in all cameras, usually a "light" oil. It is light at normal room temperatures, but will act like taffy when the weather gets cold enough. Some imported cameras are loaded with oil at the factory to protect the parts from damp salt air during shipment. When imported by authorized distributors who have repair shops staffed by factory-trained technicians, these cameras are completely cleaned and relubricated before being offered for sale. But every year a number that have not been cleaned find their way to the market. It is always wise to test a new camera thoroughly before using it for serious winter shooting. The better, newer, and more expensive cameras are lubricated sparingly with special aircraft instrument oil, which does not thicken when it gets cold but other problems are not so readily solved.

All camera mechanisms depend to some extent on springs, and springs do not maintain the same tension at all temperatures. Then there is the problem of contraction. The clearances between parts in a complicated camera are rather critical. Metal contracts slightly when cooled, but parts made of different metals will contract at different rates and the spacing between the parts will change. When a weakened spring has to push or pull against increased friction plus sluggish lubrication, it is not surprising that the results are uncertain.

In extremely low temperatures there are even changes in the structure and surface of the metal itself, for which there is no known cure. We can only try to avoid letting cameras get that cold or else we can use specially designed equipment that probably will not be much good for anything else.

Within the more usual range—down to 10° F. below zero or thereabouts there are several steps that will help. The first is "winterizing." A qualified camera repair man will take the mechanism completely apart, clean it thoroughly, and reassemble it with an absolute minimum of special non-thickening lubricant. He will adjust the clearances and spring tensions to make the parts move as easily as possible. Winterizing, like bathing, is not permanent. It must be repeated at least every fall and often more frequently, depending on the condition of the camera and how much it is used out of doors.

Any camera that is going to be out in the cold for more than a few minutes should be winterized, but that step alone does not insure that it will work. The camera should be tested at the lowest temperature at which it will be used *before* any picture is taken, and specially before any long trip during which further adjustments may be impossible. A handy way to test a camera is to put it in the refrigerator. Load it beforehand; the roll of film will be a good investment. If it works well after sitting overnight in the food compartment, put it in the freezing section. If you are going to be working in really cold weather, use a picnic ice chest or insulated food bag with dry ice. It takes four to six hours for the camera to get thoroughly chilled and, of course, you will have to make the tests quickly before it warms up. Try the slow shutter speeds and the fast ones. Move all the controls. Take a few frames of an evenly lighted blank wall at different speeds, adjusting the diaphragm for equivalent exposure (for example, 1/10 second at f.16, 1/50 at f.7 and 1/250 at f.3.2). By examining the resulting negatives, you can answer two important questions: Is the shutter speed consistent in the different ranges? Is the exposure even throughout the frame? It is also important to wind the film all the way through the camera to check the film transport mechanism.

SOME cameras stand cold better than others. In general, the simpler the mechanism, the less there is to freeze up. For this reason, one expert recommends that a press camera be carried on all cold assignments, if only as a "spare" camera. (Of course, the front shutter should be used, not the focal plane shutter.) This is good advice, although the size and weight of camera and accessories might be prohibitive for skiing, snowshoeing, or traveling by dog sl

Emil Schulthess, whose magnific book on Antarctica has just been pu lished, says that he has found focal pla shutters more resistant to cold than le shutters. In this respect, his experien is the opposite of mine (and I do n think it is because he was working in t south polar area while I was working the north). Before leaving Switzerlan Schulthess had his cameras complet overhauled at the factory and thorougl tested in cold chambers. My experien has been that focal plane shutters—t type commonly used in 35mm. camera develop a lag that causes one half the shutter to travel faster than the oth half, with the result that one side of tl negative gets too much exposure and t other side too little (*see* page 63). Le shutters, which open from the center o are more likely to give a uniform e posure, but they tend to slow down, that at a setting of 1/10 second, f example, they may actually give an e posure of 1/2 second. On twin-lens r flex cameras of the "automatic" typ the film-winding mechanism is mo likely to freeze than is the shutter. Tl film will wind all right, but it will n stop at the next frame as it should. have not yet tried any of the new single-lens reflex cameras, but I am i clined to doubt that their mirrors ar spring-operated diaphragms will wo reliably in extreme cold.

Newer cameras are more likely have cold-resistant lubrication, and son of the newer shutters (ball-bearing typ for example) are good at low temper tures, but old, well-worn cameras som times work better because of wea which has increased the clearances b tween their moving parts.

Unfortunately, the problems of ph tography in the cold do not end with tl camera. Film is also affected. Kod chrome loses 1½ stops in speed at −50°. (i.e., the normal film speed of 10 is r duced to 3½). Black and white film suffer a similar loss, and the higher tl film speed the greater the loss. For th reason, slow films should be used f winter shooting whenever there enough light. It is regrettable that r tables have been published giving e

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David Linton's by-line has appeared under photographs in all the nation's leading magazines. His camera column is a regular feature on these pages.

Snow increases contrasts, subdues details, and accents contours.

re indexes for various films at vari- temperatures, so the photographer compute exposures with a ther- eter in one hand and an exposure r in the other. Actually, in most ras, loss of shutter speed tends to pensate to some extent for loss in speed, but the results are far from ictable. If precise exposures are ired, tests under equivalent condi- are the only usable guide.

F M becomes brittle when cold and dry, and will crack or tear if sub- d to too much strain. Roll film will times chip along the edges, and times break. In 35mm. cameras the most likely to break if you advance ilm to the end of the roll and then try to wind it more while the end is held by the spool. Usually the sprocket holes tear first, and then the film will break along a jagged V. In the process, a lot of little bits of film chip off. They have sharp corners and will scratch the film beyond redemption. Because of this danger, a roll that has been partly torn should not be rewound into the cartridge. Take it out of the camera in the dark and store in a light-tight box.

Static electricity is a serious problem under winter shooting conditions. Low temperature and humidity encourage static, and wool and fur worn by the photographer probably add to it. The results can show as jagged "lightning" streaks on the negative or as rows of dots. These marks are actually the images of miniature sparks created when the film is moved. The only insurance against them is to wind and rewind the film very slowly. There is no cure for them once they are on the film, but newer films have antistatic coatings that do reduce the danger.

Winter sunshine, reflected by snow on the ground, can be so bright that the photographer is afraid to trust his light meter and will tend to overexpose. At the same time, a dark subject surrounded by white snow will be underexposed if the exposure is measured from the snow. The meter is generally a better judge of unfamiliar conditions than the eye, but it should be aimed so that it reads the brightness of the subject, rather than the background or foreground.

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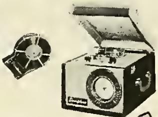

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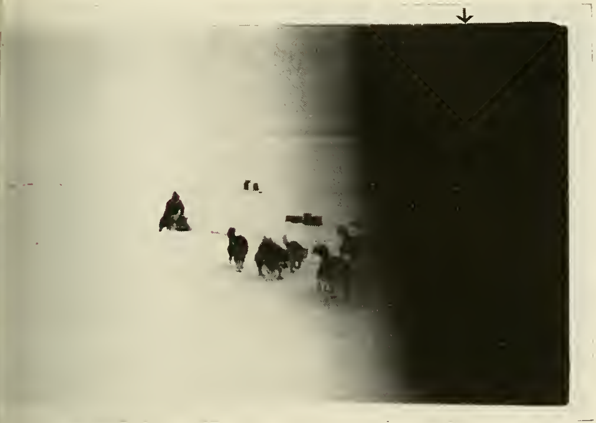
Any situation with a lot of light c ls for extra care in loading and unloa g the camera. If no shade is availa e, take off your coat, put the camera nside, and reach in through the sleeve to insert and remove the film.

The best, and the only reliable, s ution to the various problems of shoo g in the cold is to keep the camera d film warm. They need not be as warr as they would be in summer, but just w m enough to insure that they work r ably. The best way to carry a camer in winter is inside your coat. I have s n skiers tearing down icy slopes a d clouds of snow with cameras slung er their shoulders and whipping in e breeze. They cut a dashing figure, b I doubt that they get many pictures (I have had my Eskimo parka fitted wi a zipper so I can carry cameras ins e, around my neck.) If you travel by r, keep the camera inside with you, n in the trunk. If you use a gadget bag, k p it on the floor near the heater. If u travel by air, do not check camera in your baggage; it may be stowed i an unheated compartment.

POCKET hand warmers are a con nient source of warmth away f m mechanical heat sources. They ill work only in a confined space, bec se they depend on the vapor given of y lighter fluid, and the fluid will not aporize if it gets too cold. But one or vo hand warmers carried inside a ga et bag will keep the cameras and m warm well into the subzero range. S etimes it is also helpful to carry h d warmers in shirt pockets and sling a mera around your neck, under your at.

Whatever source of heat you use, e camera should be taken out only w en you are ready to shoot, and put a ay again as soon as possible. Sometime of course, this is impossible, as when e camera must be set up long in adv ce and operated either automatically o y remote control. The setups in which ld animals or birds trip the shutter d take their own pictures are a cas in point. I plan to devote a column to t se "traps," but a word about making t m work in cold is appropriate here.

Any arrangement that allows he camera to stand idle and exposed t he cold for a long time invites shutter t uble. In addition, setups using batt es as a source of energy for tripping he shutter or powering speed lights or both, are prone to battery trouble As the temperature drops the chemica eaction by which dry cells manufac re current gets slower, and thus de es that drain a lot of energy from dry lls get sluggish and finally quit. A s ed light that recharges in three secon at room temperature may take a minu or more at 10° F. below zero and prob ly will not work at all below that. e cells (the type of battery used in c s)



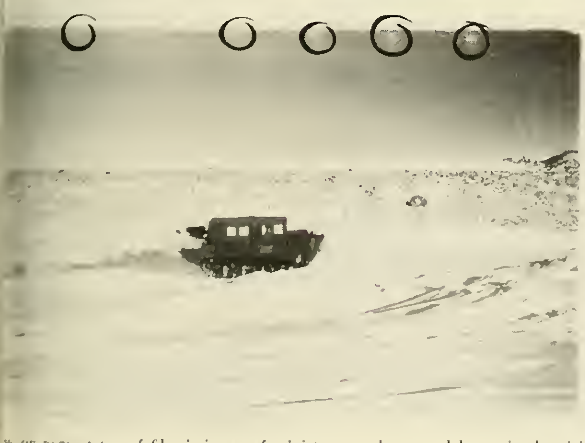
H F OF FILM is overexposed, other half underexposed when cold causes shutter to lag.

wi operate down to the freezing point o the fluid in them, which varies with th proportion of acid to water, but is u ally low enough to be quite safe. But w cells are not made in many of the si s needed for photo equipment.

)ther parts of electrical equipment a likely to go "haywire." The tripping c uits of speed lights sometimes de- v p "leaks" so that some of them will n flash at all, while others will go off b themselves every minute or so. In one c e I made use of such a self-firing unit b timing the cycle and opening the c hera shutter just before the light trig- g ed itself. But I do not recommend t procedure except for emergencies.

ERE, again, the only real solution is to keep the cameras and any asso- ted electrical equipment—*including teries*—warm enough to function normally. Where electrical power is available, the equipment can be wrapped in insulating material and kept warm with an electric heating pad or blanket. Some military cameras have been fitted with electrically heated jackets, and these occasionally turn up on the surplus market. They are usually designed to work on 12 volts d.c., the output of a modern automobile battery. I cannot think of any reason why the electrically heated flying suits and socks sold by surplus stores could not be adapted for camera use as long as the heating elements are intact. There are also chemical heating pads that get warm when water is added to them and will continue to generate warmth for six hours or so. I have not tried these because I rarely leave my cameras in one place that long, but they ought to work.

The photographer who must work



W OF DOTS at top of film is image of miniature sparks created by static electricity.

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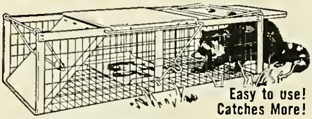
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both indoors and out, and go back nd forth frequently, really needs two sa- rate sets of cameras. On this, Schultss and I agree. A cold camera suddely brought into a warm, humid room a frightening sight. First, moisture n- denses on all the glass and metal r- faces, clouding the lens like a catact in an eye, and then the moisture frees. There is no safe way of removingit from the outside and no way at all of- moving it from the parts inside the ca- era, where the same thing happens. 'he only solution is to wait, sometimes r several hours, until the camera wa s up completely and the moisture eva- rates. Even if the camera has been kt relatively warm while outside, the i- ference may be enough to cause troue. The best procedure is to use one cam a indoors and another outside, keepg the "outside" one where it will not et too cold but where it will not be b- jected to sudden temperature rises.

No camera on the market can be - erated properly by a man wearing t- tens. This is inconvenient, but not lily to be changed. I wear thin gloves in le mittens. Even in very cold wea er I can take the mittens off long enogh to work the camera with gloves al e.

From all this it may sound as if best advice would be to leave the c era at home until spring. Nothing be further from the truth. Man nary subjects become exciting in winter, and recording ther worth the few precautions it re In particular, snow is the phot pher's friend. By subduing details it phasizes lines and contours; it increas color and brightness contrast, and it - flects light into shadows. It can mak a strong composition out of a scene it would be too "busy" in summer.

And photography probably offers e only acceptable excuse for the nat e fan who wants to be outdoors in winr. Indoor types are accustomed to the i a that we who take pictures are all ju a little balmy, and that seemingly i a- tional behavior is normal among us. o when one wants to go for a bracing e in a blizzard, it is convenient to be e to say, "Oh, I think I'll just go out d take a few pictures."

This list details the photographer, ar t, or other source of illustrations, by p e.

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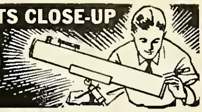

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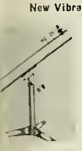

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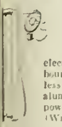

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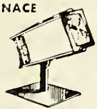

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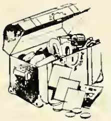

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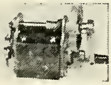

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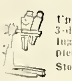

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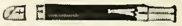

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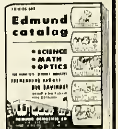

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COVER: This bull's head, with the four-bladed ax between its horns, is actuall only an inch across. It is one of some twenty-five Mycenaean gold foil specimen now in the Athens Museum. Until Michael Ventris demonstrated that the little known Mycenaeans were Greek-speaking, the culture that produced such rar art was shrouded in mystery. Ventris' incredibly complex work is describe in *The Decipherment of Linear B*, by John Chadwick (© 1958, by the author here excerpted by NATURAL HISTORY, beginning on p. 8. In April, Chadwic continues the story with a masterful reconstruction of everyday Mycenaean lif

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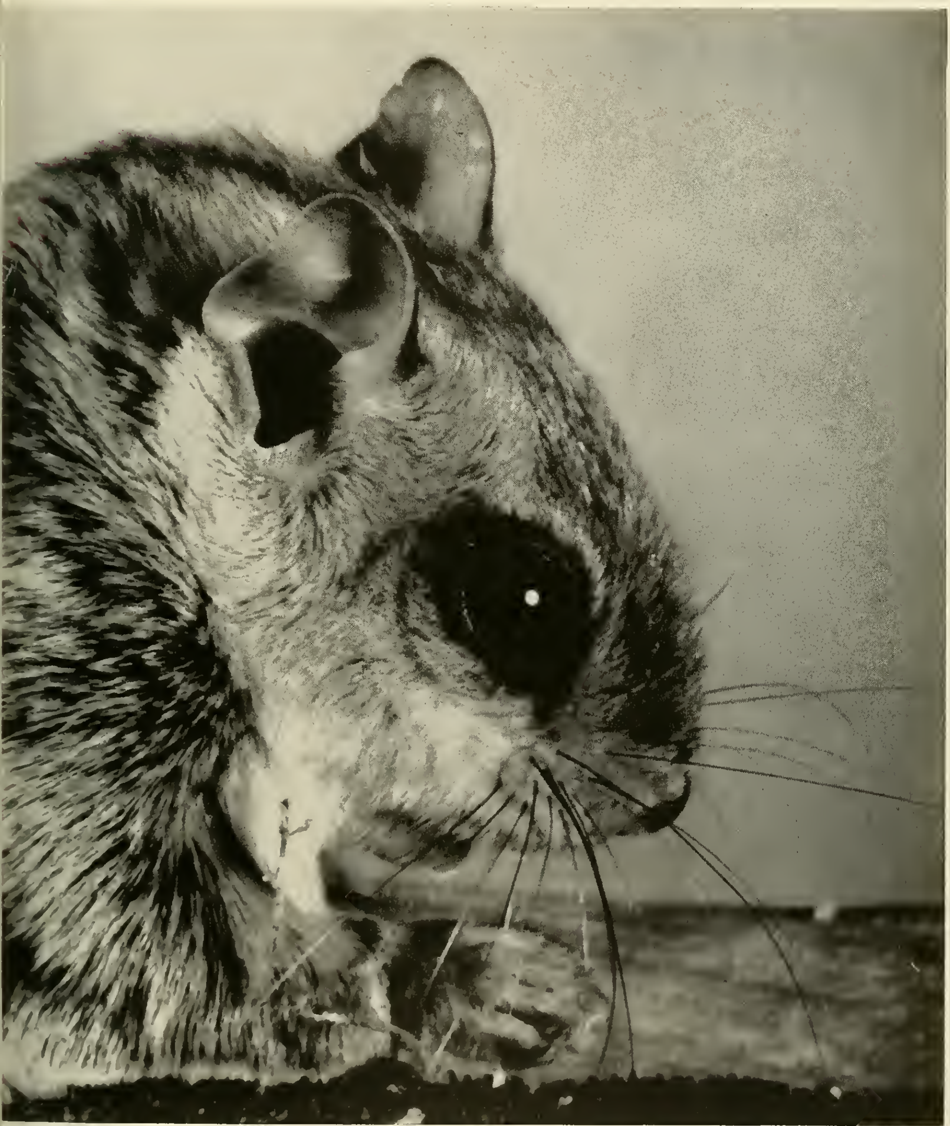

This is an enlargement of just the head from the picture of the flying squirrel we ran in the August-September issue of this magazine. We thought you might like to have a closer look at this delightful creature who is really only the size of a mouse. Since this part was only about one-eighth of the 35mm. film frame, it indicates something of the detail Questar will let you see or photograph at thirty feet.

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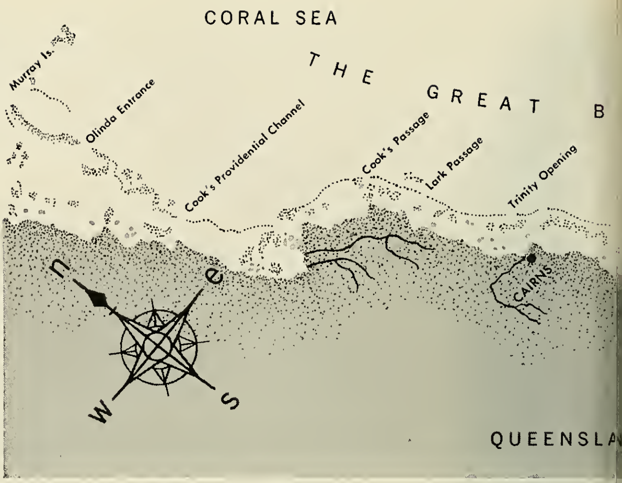


Reviews

A new guide to the Great Barrier Ree

By DONALD F. SQUIRE

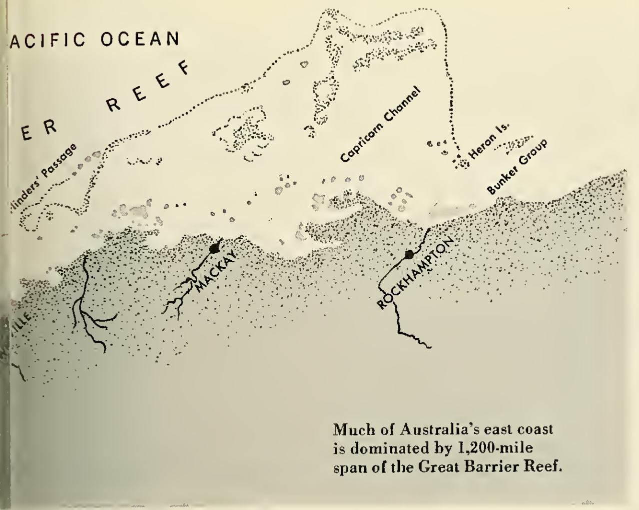
THE GREAT BARRIER REEF AND ADJACENT ISLES, by Keith Gillett and Frank McNeill. *The Coral Press, Sydney, Australia, $10.00; 194 pp., illus.*

ONE of the greatest constructions of nature, the coral rampart known as the Great Barrier Reef of Australia, ranks among the lesser known areas of the world. From the Coral Sea and Torres Straits to the north and northeast, the reef stretches southward in a long chain of islets, submerged shoals, and banks of coral, losing continuity at about the Bunker Group but continuing, nonetheless, in an enfeebled way to the coast of New South Wales in the latitude of Sydney. Much of its 1,200-mile-long extent has not yet been mapped in detail, although some 350 years have passed since its first discovery and nearly 200 years since the first charts of the reef were prepared by Captain James Cook.

This reef is the product of the industry of untold millions of coral polyps, whose secretions of lime skeletons, one on top of the other, have accumulated into the massive barrier, building steadily upward. These minute polyps, often no more than a few millimeters in diameter, live under rather restricted conditions, requiring clear, warm, marine waters, and bright light. Because of this, the reef-forming corals are not found in temperate waters, nor are they found belo
about 90 meters even in the Tropics.

Charles Darwin was aware of these r
strictions in the habitats of the cor
animal and, as a result of his caref
observations of many coral reefs, broug
forth his famous hypothesis of coral re
formation. Although not as widely pu
licized as his later evolutionary do
trines, Darwin's coral reef theory stirr
up nearly as much controversy at th
time. The debate still continues, a
though it has now greatly diminished.

Among the reef types recognized l
Darwin was the barrier reef and, in th
class, the Great Barrier Reef of Au
tralia specifically. In general, Darw
postulated that if the shallow shelf of
continent were to subside slowly, but
such a rate that the upward growth
the corals could keep pace, a rim
coral along the outer edge of the she
would be formed. An alternative theor
proposed many years later, suggests th
the solution is not as simple as Darwin
postulate, that subsidence is not the on
factor, but that changes in sea level a
also of significance. Adherents of th
theory state that the return of sea wat
from the low levels that occurred durin
the last ice age is the factor most r
sponsible for control of the upwa
growth of the reef (NATURAL HISTOR
March and April, 1959).



Much of Australia's east coast is dominated by 1,200-mile span of the Great Barrier Reef.

Whatever the cause or control, the corals and their limy skeletons are the building blocks of the reef fauna. Associated with these corals are calcareous algae. minute plants that nonetheless contribute the bulk of material to the reef; the mollusks, both clams and snails in great profusion; the crabs and lobsters; the brightly colored worms and nudibranchs. and the fish. Together. all these and a host of others constitute the reef fauna. and perhaps nowhere else in the world is there a reef fauna so luxurious, so colorful, so admirably displayed as that of the Great Barrier Reef of the Australian east coast.

DESPITE the importance of the Barrier Reef as a biologic, physiographic, and economic factor. it has not been biologically exploited as much as one might suspect. With the notable exception of the 1928-29 British Great Barrier Reef Expedition. there have been only solated research reports dealing with he Reef. Of late. this situation has gradually improved and. with the recent establishment of a much-needed marine biological station on Heron Island, it is nore than likely that the quantity of research will continue to increase. Isolaion and the vast size of the reef are the actors that have largely contributed to the lack of scientific endeavor. Before he advent of air travel, Australia was remote from much of the scientific world, and her own scientists were engaged in economic and developmental tudies. Even for the intrepid, access to he Reef was not always easy. Few islands were inhabited and transportation was irregular at best. Nonetheless, some great work was accomplished.

W. Saville-Kent, of the British Museum (Natural History), conducted a study of the Great Barrier Reef that resulted in the publication in 1893 of a massive tome expounding all phases of the Reef. This remained the standard treatise on the subject until the Great Barrier Reef Expedition of 1928-29. At that time, a group of nineteen scientists, many of whom spent a year at the Low Isles Station, conducted not only ecological and biological surveys but were able to perform basic physiological experiments upon reef organisms, many of which are unrepeated to this day. The scientific reports resulting from the manifold investigations of the group were published in a number of impressive volumes, the latest of which did not appear until 1957. Since this expedition, there has been no organized, large scale investigation of the Great Barrier Reef, largely due to a general absence of funds. The Great Barrier Reef Committee, which organized the 1928 expedition, remained in existence and has published a long series of minor reports on the Reef. Only recently has the Committee been able to focus attention again on the Reef and, through the donation of private funds stimulated by a resurgence of local interest, it has been able to open a biological station. This station will provide not only facilities but adequate laboratory opportunities both for students in Australia and for visiting scientists from overseas.

Heron Island, in the Capricorn Group, is one of the few islands away from the shore that is accessible to most persons. Therefore, it is not surprising either that it became a tourist resort or that it is

DR. SQUIRES, of THE AMERICAN MUSEUM, has a firsthand knowledge of Australia's Great Barrier Reef.

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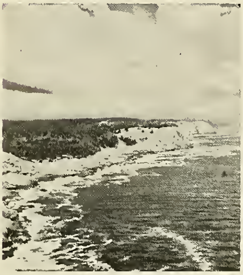

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second only to the Low Isles in extensiveness of biological investigation. Because of suitability in climate and a location near enough to the outer barrier so that the rim of the Reef can be reached under ideal conditions, it has become the site of the new Great Barrier Reef Committee Research Station. Here, in very admirable quarters, which in a short time will be fully equipped, it is hoped that new intensive studies of the Great Barrier Reef will be carried out. Certainly, the ease of transport from Brisbane—the site of the University of Queensland, which has an active Marine Biology program under the direction of Professor W. Stephenson—should both encourage a greater number of Australians to study their unique biological exhibit and foster the visit of a great number of overseas tourists.

Despite its many grandeurs, the Reef has not inspired many popular narratives of distinction. One of the earliest remains one of the standards, largely because of the magnificent quality of its illustrations. The lavish tome by Saville-Kent, published in 1893, gave the world its first glimpse of the Reef. A series of fifty photographs, taken on slow plates by Saville-Kent himself, showed the region of the northern reef, particularly that of Thursday Island as the Reef was exposed at spring low tides. In a number of other plates, many of the organisms, particularly the fish, were illustrated.

Another important contribution to literature on the Great Barrier Reef came from the pen of the leader of the 1928-29 Great Barrier Reef Expedition, C. M. Yonge. Excellent though it is, his book suffers from the same fault as Saville-Kent's. Although it is the result of an intimate knowledge of a section of the Great Barrier Reef, it was not intended as a general guide to the Reef in the sense of a naturalist's handbook. Other contributions include T. C. Roughley's immensely readable *Wonders of the Great Barrier Reef*, which for fifteen years was the staple item of the voyager, and more recently *The Great Barrier Reef*, by William Dakin. The latter is not an outstanding work and is not particularly well illustrated. Arthur Clarke's *The Coast of Coral* is, of course, an out-and-out adventure story.

THE absence of a naturalist's handbook for the Great Barrier Reef, its fauna and flora, has been somewhat rectified by the appearance of the work reviewed here, *The Great Barrier Reef and Adjacent Isles*. McNeill is retiring Curator of Invertebrate Zoology at the Australian Museum in Sydney, and Keith Gillett is one of Australia's leading nature photographers. This book avoids many of the pitfalls of earlier works; it is more convenient than Saville-Kent's in bulk, is more profusely illustrated than any of its predecessors, and is more informative than some. The book will probably spawn many competitors, but at the moment its success seems assured. It has 170 photos, 134 in full color.

Following a frontispiece showing the Great Barrier Reef in its early morning blaze of glory, McNeill opens the "comprehensive survey for visitor, naturalist and photographer" with a discussion of the Reef's character, structure, and development. Here one is introduced to the Reef's history (all too briefly presented), its distribution, growth, and composition. In the second of twelve chapters, considerable attention is paid to the Capricorn Group, and Heron Island in particular. Although the detai may seem unwarranted to a strange (for, after all, Heron Island is but on of the thousands of islands on the Reef) the fact remains that Heron Island is, a this time, about the only true coral islan that the tourist, naturalist, or photographer is apt to reach without great expense and effort. McNeill has been abl to capture the charm of the coral islands and for the traveler (naturalist or photographer) who is not so aquatic as th marine fauna of the Reef, there is considerable meat in this chapter (an Chapters 9 and 10, describing Cumberland and Lord Howe Island, respectively) on the terrestrial flora and fauna

MCNEILL then turns to the anima kingdom. In successive chapters he considers "Corals and their Allies, outstanding coastal and reef shells, se stars, sea-urchins and their relation other spectacular members of reef fauna (fish, worms, large crustacea), an finally, "Crabs and Smaller Crustaceans. While some invertebrate zoologists ma cheer the fearless fashion in whic McNeill has devoted 27 pages to coelenterates (including 5 illustrations) an 29 pages to other invertebrates, whi giving over only 31 pages to the shells so near and dear to the bookseller hearts—the beach tramper may wish supplementary guide to the shells of t Barrier Reef. Nonetheless, Gillett ha managed to cram 150 species into his 4 plates without losing balance elsewhe in his book. If the photographic prese tation suffers at all, it is in the section corals for, despite Gillett's abilities as diver, very few color illustrations of t reefs below the tide mark are given. fact, there are less than a half-doz photographs in the book that appe to have been taken underwater. None these equals the quality of earlier effor and certainly are drab in comparison the gaudy showpieces of Clarke's *T Coast of Coral;* and the angler or spe fisherman seeking to identify his cat will not be pleased with the summary d regard the authors have given the mem bers of the Class Pisces.

Among the more interesting chapters s one entitled "Night Descends on a Coral Reef." Normally, the hours of larkness at tourist resorts are given over o activities other than that of prowling about a reef. Although McNeill's chapter is not likely to bring about mass reversal of the human activity cycle on he Great Barrier Reef, it will at least uggest to the interested reader that the Reef does not rest at night.

Elizabeth Pope, Curator of Invertebrate Zoology at the Australian Museum has contributed a most comprehensive chapter on Lord Howe Island. This speck of land, about 350 miles northeast of Sydney, New South Wales, is the southernmost coral reef in the world. It is also one of the most spectacular bits of tropical scenery anywhere in the world. Scientifically, much is known about the errestrial fauna, but next to nothing about the marine. Until recent times, Lord Howe Island was more or less a pecial preserve of the Australian, a ovely retreat booked solidly year after year. It is hoped that *The Great Barrier Reef and Adjacent Isles* will put this pot of land back on the map, as it were. t is clear that this description of Lord Howe Island is a labor of love.

The final chapter of the general text—n the potential resources of the region—is decidedly out of place in a book f this sort. Aside from the fact that ittle information is given, it seems to ave been written to cure insomniacs.

Keith Gillett has contributed a supplementary chapter on marine photogaphy. Although it is undoubtedly uthoritative, the level of writing seems o have been pitched a bit high. The ank amateur will find little to sustain im; the professional may well have ncountered most of this information. Most Americans will be impressed by he number of underwater camera housngs seen in Australia, but most are ome-built. For the visitor, then, local dvice must be sought, preferably before oing to the reef areas, for once away rom Sydney, prices of most items of photographic equipment, particularly lm, increase at astronomical rates.

Appendixes concerning protective reglations and practical hints, although nly a page each in length, will unoubtedly be ignored, with the usual onsequences. It is hoped that future ditions will have an expanded version f hints, furnishing a little more detail n how and where to look for various rganisms. Many overseas visitors will e quite unfamiliar with a reef and will e interested in more specific details. A ibliography of identification references would not be misplaced, for many persons will be stimulated to further efforts y the book. The addition of magnification data to those plates on which it is acking will be an absolute necessity.

Birds of North Carolina, by T. G. Pearson, C. S. Brimley, and H. H. Brimley, and revised by D. L. Wray and H. T. Davis. *North Carolina Department of Agriculture, $5.00; 434 pp., illus.* by Brasher, Horsfall, and Peterson.

This represents the third revision of one of the first comprehensive books on the birds of any of our southern states, which first appeared in 1919. The text of the second edition (1942) has been kept in the present volume almost without change and, where new distributional records have been accumulated since 1942, these are appended as a footnote to each species' account. There are no bibliographic citations to document any of these additions, however. The practice of writing a full account for each species *and* subspecies has been continued. New accounts have been added for the sixteen forms added to the 1942 list, making a current total of 412 species and subspecies for the state. A map and very brief text on the life zones of the state have been added.

It is regrettable that so little effort has been made to edit or revise the original text. The statement by the earlier authors that only one nest of the Connecticut warbler has ever been found has not been corrected. No effort has been made to discredit the once popular belief that the woodcock carries its young between its thighs. That cowbirds "are social outcasts" and that, "as a rule, other birds do not associate with them" should come as a complete surprise to bird watchers even in North Carolina. Credence is still given to the myth that "a young cowbird will push other young from the nest in which it is hatched."

Some of the plates come from Peterson's *Field Guide*, while some, but not all, of the rather poor line drawings dating back to the 1919 volume have been omitted. The reproduction of some of the Peterson plates, and especially of the colored plates by Horsfall that appear in my review copy, are the worst that I have ever seen in any book on birds.

In sum, the North Carolina Department of Agriculture would have done far better merely to issue an addendum to the earlier editions, perhaps through the medium of the State's own ornithological journal, *The Chat*. The purported objective, to bring the sections on geographical and seasonal distribution up to date, would thus have been accomplished at considerably less cost. But, of greater importance to ornithology, the misconceptions and erroneous observations embodied within the earlier text would not have been perpetuated and re-emphasized for the younger generation of ornithologists in North Carolina and neighboring states.

Wesley E. Lanyon,
The American Museum

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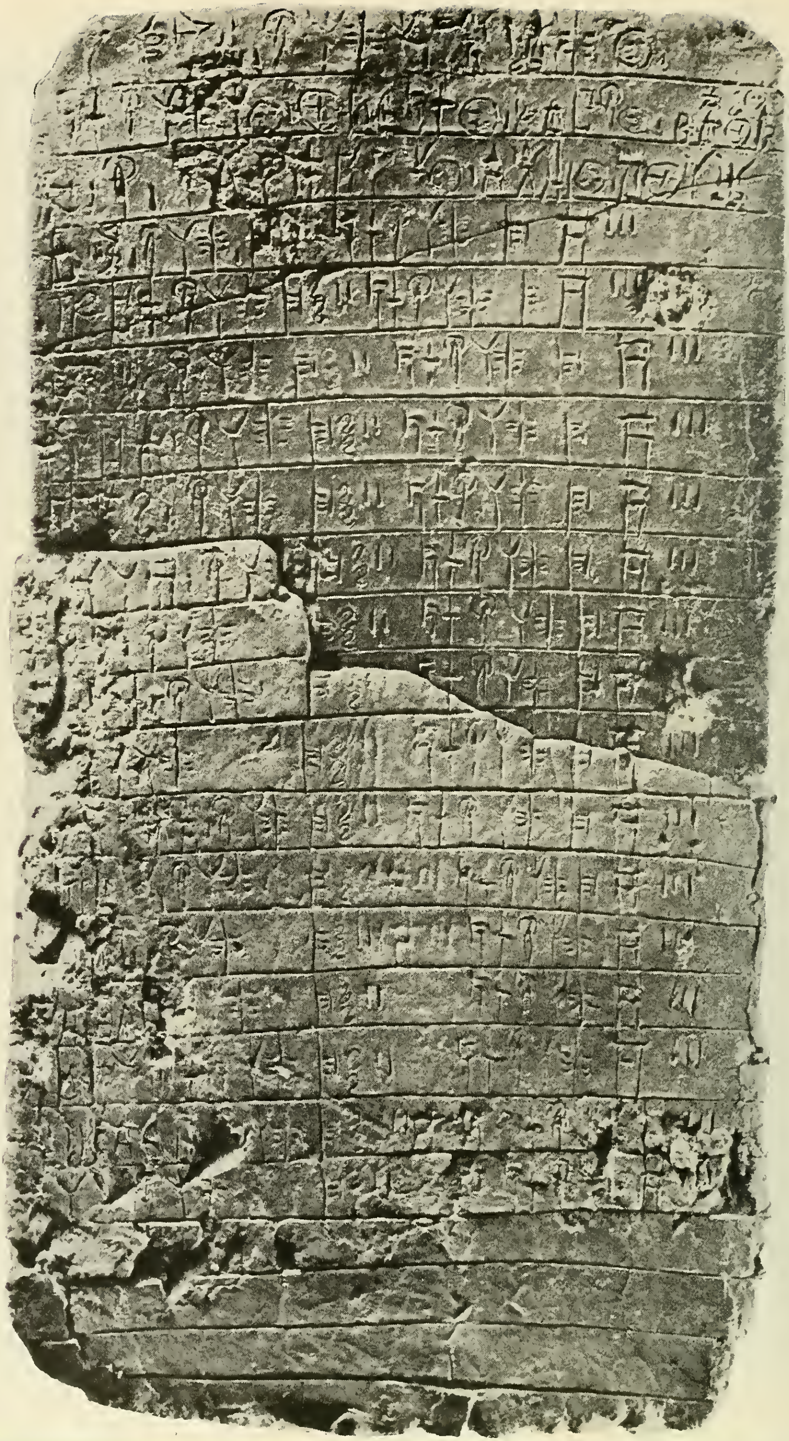


The Decipherment of Linear B

A once-lost language, in an unknown script, can now be read

By John Chadwick

The year 776 B.C. witnessed the first Olympic games, a festival, which all the Greeks kept at the precinct of Zeus at Olympia in the northwest of the Peloponnese. Whether it was really the first is doubtful, but it was so reckoned by the later Greeks whose records went back to that date. This is a significant date in Greek history because it marks and symbolizes the adoption in Greece of the Phoenician alphabet. from which ultimately all other alphabets are descended: from the eighth century B.C. onward the Greeks were a literate people. able to record their own history. Thus, Greek history in the strict sense may be said to begin then, and what lies before that date can be termed prehistory. But this was no more the beginning of Greek history than 1776 was of American. Long before the first Olympic games, men and women had lived, fought, and died among the mountains and islands of Greece, and by the only test which can properly be applied—that of language—they were as Greek as their better-known successors in golden Athens and harsh Sparta.

There are three ways of penetrating the fog, which blots out the early stages of the development of the Greeks; none of them satisfactory or offering more than scraps of information. but by a cautious synthesis allowng some general conclusions. First. there is the memory of people and events that survived into a literate era. The Greeks of the classical period had many legends of a remote past. a heroic age when men were capable of heroic eats and the gods were always at hand to help; many of he heroes were the sons of gods or goddesses. There are wo notable events recorded in these legends: the war gainst Thebes in Boeotia and the expedition against Troy.

The latter is better known. since it provides the background for the twin masterpieces of Greek literature. Traditionally the work of Homer, these long epic poems seem o have acquired their present form somewhere toward the nd of the eighth century B.C.—again that significant cenury, when writing changed much of the Greek way of ife, not least its poetry. Much in the Homeric tale is clearly due to the imagination of the bards. But here at least is a strong pointer to a period of Greek prehistory when the country was organized in strong kingdoms centering round Mycenae—although. in historical times, this was no more than a small country town.

The prospect was enough to persuade a romantically minded German businessman of the nineteenth century, Heinrich Schliemann, to devote his time and wealth to the pursuit of this forgotten age. Thus was forged the second tool of the Greek prehistorian, archeology. With the amateur's faith and enthusiasm. Schliemann set out, Homer in hand, to bring to light the god-built walls of Troy.

This is not the place to record Schliemann's career in detail, but we must recall his momentous excavation of 1876, when he found the famous grave circle at Mycenae. For it was the revelation of the wealth and artistry of the civilization he unearthed that convinced scholars of the essential truth behind the legends. "Mycenae, rich in gold, . . ." sang Homer; and the gold came from the shaft graves in quantities to stagger even Schliemann. It took years of patient work by Schliemann's successors to establish the pattern of events that can now be traced in outline.

Pre-Hellenic archeology, as it has been called until recently, distinguishes three phases of the Bronze Age in Greece: Early Bronze (roughly 2800-1900 B.C.); Middle Bronze (1900-1650 B.C.); and Late Bronze (1650-1100 B.C.). The great flowering of civilization took place first in Crete in the Middle period, culminating in a violent destruction about 1400 B.C. On the mainland, it took place rather later, beginning with the Late Bronze Age and lasting until the twelfth century B.C., when, one after another, all the important centers of Greece were sacked and left in ruins. This last period is called, after the first site to be excavated and its chief center, Mycenaean.

Among the many scholars who were in Athens in the 1890's to see the Schliemann treasures was an English scholar named Arthur Evans. His appreciation of the high level of civilization reached by these Mycenaeans led him to speculate on the economic structure of a kingdom wealthy enough to produce such art and monuments. Evans thought that the Mycenaeans must have been able to write: but no inscriptions had been found in their graves and palaces, and the Greek alphabet—as we have seen—was borrowed from Phoenicia two or three hundred years after Mycenae of the Bronze Age fell.

Example of Linear B tablet, *left*, comes from the Pylos ite, first excavated by Blegen before World War II. Now eadable, it speaks of a contribution of bronze for ships.

Mr. Chadwick, Lecturer in Classics at the University of Cambridge, is author of *The Decipherment of Linear B*, excerpted here with his and the publisher's permission.

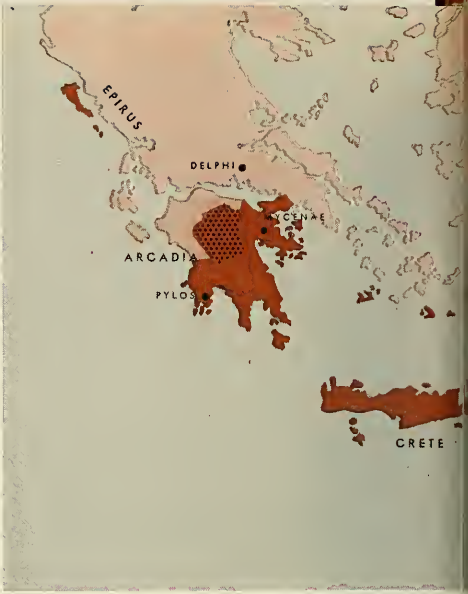
It was this speculation that spurred Evans to search for traces of prehistoric writing: his attention was attracted by some engraved gems that could be found in the antique dealers' shops in Athens. Some of them had arbitrary collocations of signs, which might represent a kind of script. Evans traced these to Crete, where they were frequently worn by peasant women as charms; the women called them "milk stones." From their study, Evans first identified the earliest script of Greece.

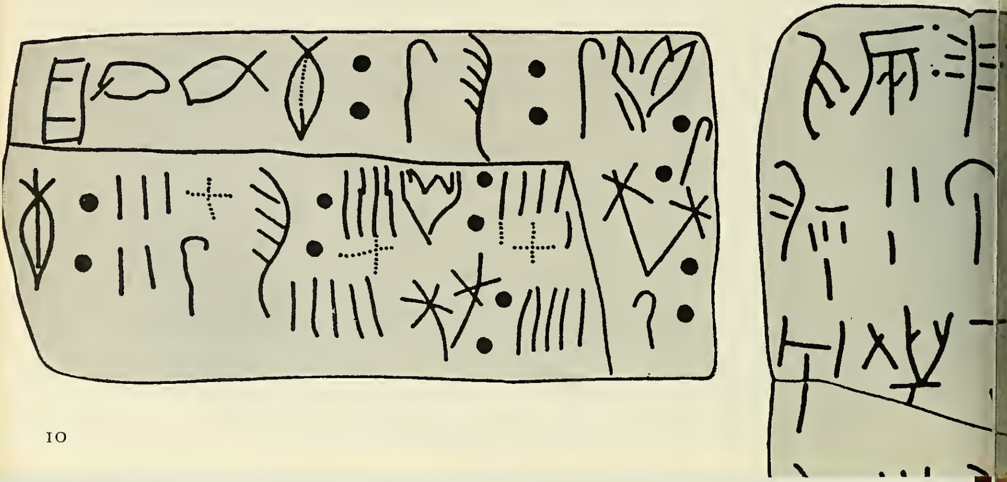
But this was not enough. A few characters engraved on gems were no evidence of the bookkeeping needed to run a civilized country. In 1900, as soon as the liberation of Crete from Turkish rule opened the way, Evans began the excavation of a site already well known as that of Knossos, a classical town of importance and, if Homer can be trusted, the royal seat and capital of a legendary empire. His primary object, the discovery of writing, was rapidly accomplished: the first tablets were found only a week after he had started to dig.

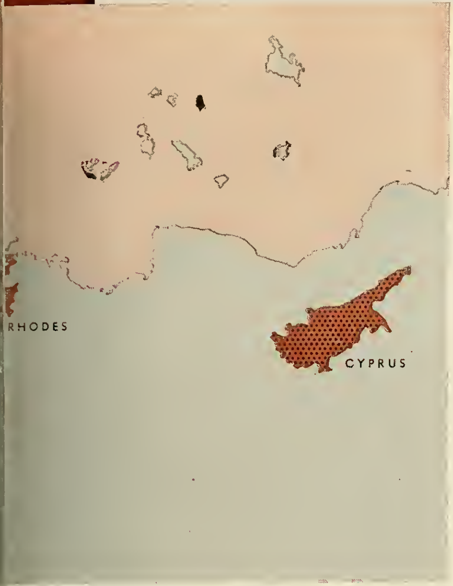
The third method of penetrating the fog of Greek prehistory is even more difficult to follow correctly than the analysis of legend and the often scanty evidence of archeology. Even today it is all too often overlooked. This is the study of the Greek language. When the earliest alphabetic inscriptions were made, in the eighth century B.C., every little state in Greece had its own dialect. These dialects may be grouped into four main divisions, although these do not correspond in geographical distribution. Quite unlike dialects had a common frontier, while similar ones were widely separated. From these facts, two conclusions may be drawn: first, at one time, all these Hellenic peoples had ancestors who spoke alike, but their unity was broken, and the main divisions developed separately. Second, just before the historical period, each local dialect must have developed out of its own division.

We can apply these facts to the archeological picture with some confidence. It used to be thought that at least three of the four main divisions of dialects had evolved outside Greece and been brought in by successive invasions. This theory has been modified by new research and it now seems more likely that the breakup of the dialects began only after the entry of the Greeks into the Balkan Peninsula. This event has been plausibly equated with the archeological break between the Early and Middle Bronze Age cultures, about 1900 B.C. At most sites there is evidence of destruction at this period, and the new culture shows some features radically different from the old.

The final stage of the movements of the Hellenic peoples is even better defined. The chief areas of Mycenaean power, the sites of the palaces destroyed about the thirteenth to twelfth centuries B.C., were in historical times occupied by one of the major linguistic groups, the Dorians. Starting from northwest Greece (Epirus), these dialects lay in a great arc running down the west coast of the Peloponnese, through Crete, and up to Rhodes and Cos in the Dodecanese. Inside the arc, the Dorians penetrated







Linguistic evidence of Dorian conquest is seen in this plotting of Greek dialects about 400 B.C. The isolated pocket of Arcadian dialect in the Peloponnese matches the related dialect on Cyprus, a known Mycenaean colony.

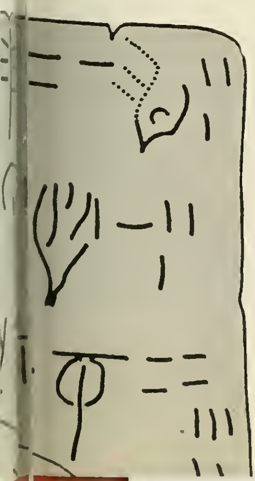
entral Greece as far as Delphi, and absorbed the whole of he Peloponnese except its mountainous core, Arcadia, hich remained a separate linguistic enclave. But they ever penetrated to the islands of the central Aegean, or o the east coast of the mainland north of the isthmus. This ange, combined with legends about the Dorian conquest, akes it extremely probable that it was this Dorian movement that caused the final collapse of Mycenaean power.

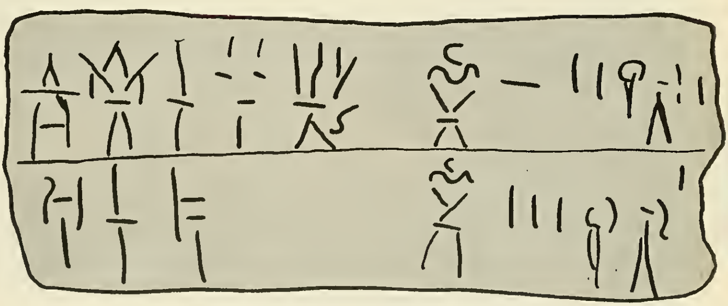
Linguistically, therefore, there was good reason to reard the Mycenaeans as Greeks. What was especially sig- ificant is that Arcadian, the isolated dialect of the central eloponnese, is closely related to that of a very remote rea, Cyprus. But Cyprus was known, archeologically, to ave been colonized by Mycenaeans in the fourteenth and hirteenth centuries B.C. Thus it was almost certain that rcadian and Cypriot, together, represented the relics of Mycenaean dialect, spoken all over the pre-Dorian Pelo- onnese. This deduction supplied an important control on the attempts to decipher a Mycenaean script as Greek. Any solution seriously out of line with Arcadian would have little chance of being a correct one.

There are only three basic ways of committing language to writing, and all known graphic systems use one or a combination of these. The simplest method is to draw a picture to represent a word; these pictograms are then often simplified until they become unrecognizable, but the principle remains that one sign represents one word. This is called "ideographic" writing, and it has been carried to the highest stage of development by the Chinese. For instance, 人 is man, 女, woman; non-pictorial concepts have of course to be expressed by oblique means: thus 大 is big—it may be a picture of the fisherman telling how big the one was that got away! Or 目, eye (much modified), is equipped with a pair of legs 見 to mean to see. Even in Western languages, we still use ideograms. For example, 5 is not a sign for five, but for the concept of five; it may be read as *cinque, cinq, cinco,* five, *funf, piat', pende,* and the like.

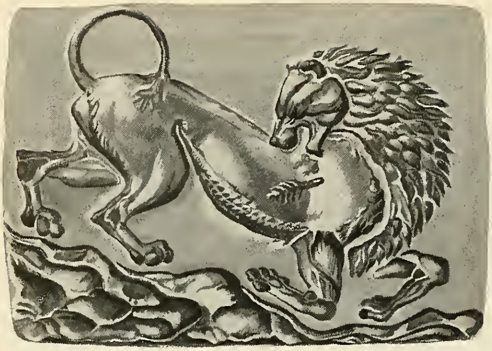
The other two writing systems are both made up of elements that, taken together, represent the sound of the word. Thus, a number of signs are needed to write all but the shortest words. The difference between them is that the units of sound represented by the signs may be either whole syllables (pronounceable) or single letters (partly unpronounceable abstractions). A syllabic system splits words up like a child's first reading book: thus "in-di-vi-du-al" would require five signs. The total number of signs needed is obviously much less than the many thousands that the ideographic system requires. But it may still be high if the language, like English, uses many complicated groups of consonants.

Alphabetic writing, the third system, is generally held to be a Semitic invention (although the Egyptian script pointed the way to it) and it was only fully developed by the Greeks. Its characteristic feature is the small number





All three puzzles are illustrated here: the oldest, or hieroglyphic, script is at left; Linear A, also not yet deciphered, is at center; a sample of Linear B, like the tablets from Knossos, is seen at the right. This specimen was found at Pylos.



NON-VERBAL INSIGHTS into Mycenaean life, before tablets could be read, are seen here. *Above,* gem-cut, wounded lion.

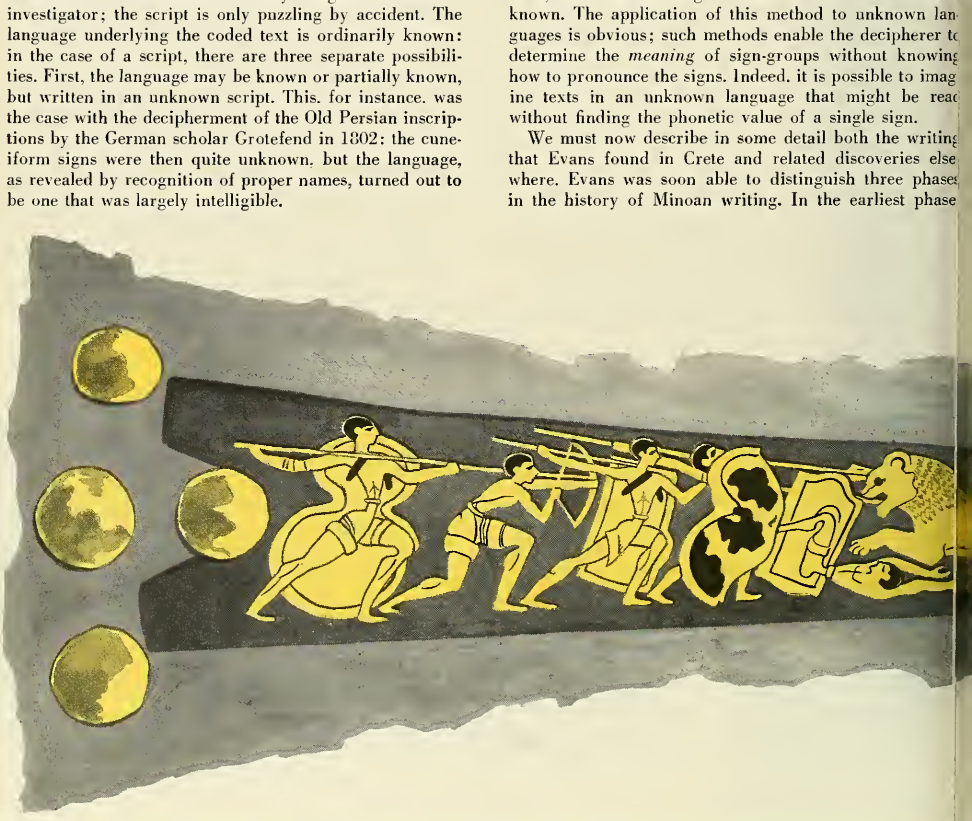
of signs needed. Thus, we use twenty-six letters in English (some redundant, like C, K, and Q—all for the same sound in some words), while the more complicated alphabets rarely exceed the thirty-two of modern Russian.

THERE is an obvious resemblance between an unreadable script and a secret code: similar methods can be employed to break both. But the differences must not be overlooked. The code is deliberately designed to baffle the investigator; the script is only puzzling by accident. The language underlying the coded text is ordinarily known: in the case of a script, there are three separate possibilities. First, the language may be known or partially known, but written in an unknown script. This, for instance, was the case with the decipherment of the Old Persian inscriptions by the German scholar Grotefend in 1802: the cuneiform signs were then quite unknown, but the language, as revealed by recognition of proper names, turned out to be one that was largely intelligible.

Second, the script may be known, but the language unknown. This is the case with Etruscan, which is written in a modified form of the Greek alphabet that presents little difficulty to the understanding of its sounds. But no language has yet been found sufficiently closely related to Etruscan to throw any light on the meaning of the words. Thus, in spite of a large collection of inscriptions, our knowledge of this language is still very elementary and uncertain. Last, we have the combination of an unknown script *and* an unknown language. In such a case, decipherments have usually been judged to be possible only when they could start from a bilingual text. The Egyptian hieroglyphs began to yield their secret only when the Rosetta stone—with the Egyptian text repeated in Greek—made it possible to equate the royal names in the two versions.

Cryptography has contributed a new weapon to the student of unknown scripts. In theory, any code can be broken, provided sufficient examples of coded texts are available. The detailed procedures are irrelevant, but the basic principle is the analysis and indexing of coded texts, so that underlying patterns and regularities can be discovered. If a number of instances can be collected, it may appear that a certain group of signs in the coded text has a particular function; it may, for example, serve as a conjunction. A knowledge of the circumstances in which a message was sent may lead to other identifications, and from these tenuous gains further progress becomes possible, until the meaning of most of the coded words is known. The application of this method to unknown languages is obvious; such methods enable the decipherer to determine the *meaning* of sign-groups without knowing how to pronounce the signs. Indeed, it is possible to imagine texts in an unknown language that might be read without finding the phonetic value of a single sign.

We must now describe in some detail both the writing that Evans found in Crete and related discoveries elsewhere. Evans was soon able to distinguish three phases in the history of Minoan writing. In the earliest phase



dated very roughly to 2000-1650 B.C., the script consisted of pictorial signs, representing generally recognizable objects, such as a head, a hand, a star, an arrow, and so forth. This was the script of the seal stones, but Evans also found a few examples on lumps of clay used as sealings and on clay bars. He named this style "hieroglyphic."

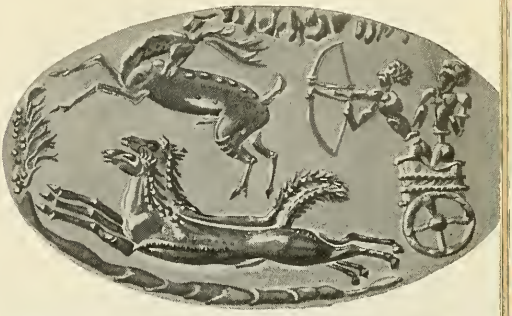
His next stage dates roughly from 1750 to 1450 B.C., perhaps beginning even earlier. Since the pictorial signs are now reduced to mere outlines, Evans named it Linear A. Examples of this style have been found all over Crete but not outside it (if we except potters' marks found at Melos and Thera). There are a number of inscriptions on stone and bronze objects. The largest single collection of documents, however, is a group of about 150 clay tablets from a Cretan palace, a few miles from Phaistos.

At some date, which cannot yet be precisely determined, Linear A was replaced by a modified form of the script—to which Evans gave the name Linear B. The date of this change would be highly significant; but unfortunately Linear B has so far been found at but one site in Crete. Although the documents using Linear B are firmly dated to the destruction of the palace at Knossos (about 1400 B.C.), it is not clear when Linear A went out of use there.

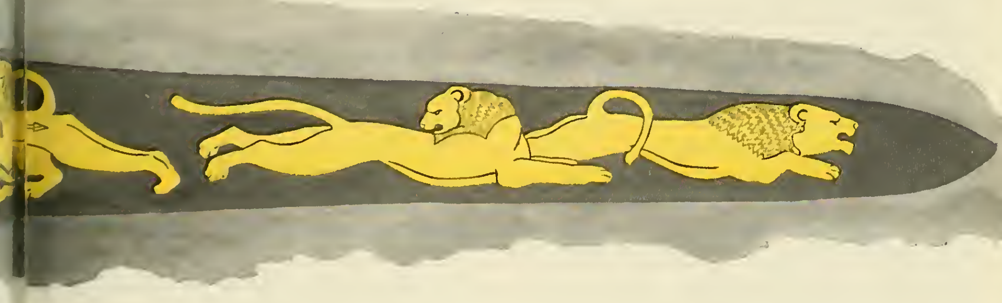
The relationship between the two systems is perplexing. It is not simply a matter of reducing the early signs to simpler and more easily written forms. In some instances, the Linear B forms are more elaborate than their Linear A counterparts. Now, there is no reason to change the form of a sign in order to write a new language, though it may be necessary to add or subtract, or change the values of, some signs. French has basically the same alphabet as English, though there are certain additional letters (à, ê, etc.); k and w are virtually ignored: and some letters have different sounds. The differences between Linear A and Linear B are more like those between the Greek and Roman alphabets (e.g. A=A, B=B, but Γ=G, and Δ=D).

Though superficially alike, the differences between the two scripts are clear to a practiced eye. A very obvious difference is that the guide lines, or rules, that separate the lines of writing on Linear B tablets are usually absent in Linear A. A further difference concerns the numerical system. In general, this is very similar, but the treatment of fractional quantities is quite different. Linear A has a system of fractional signs, not yet fully worked out; Linear B has no signs of this type, but records fractional quantities in terms of smaller units (as with tons, hundredweights, and pounds).

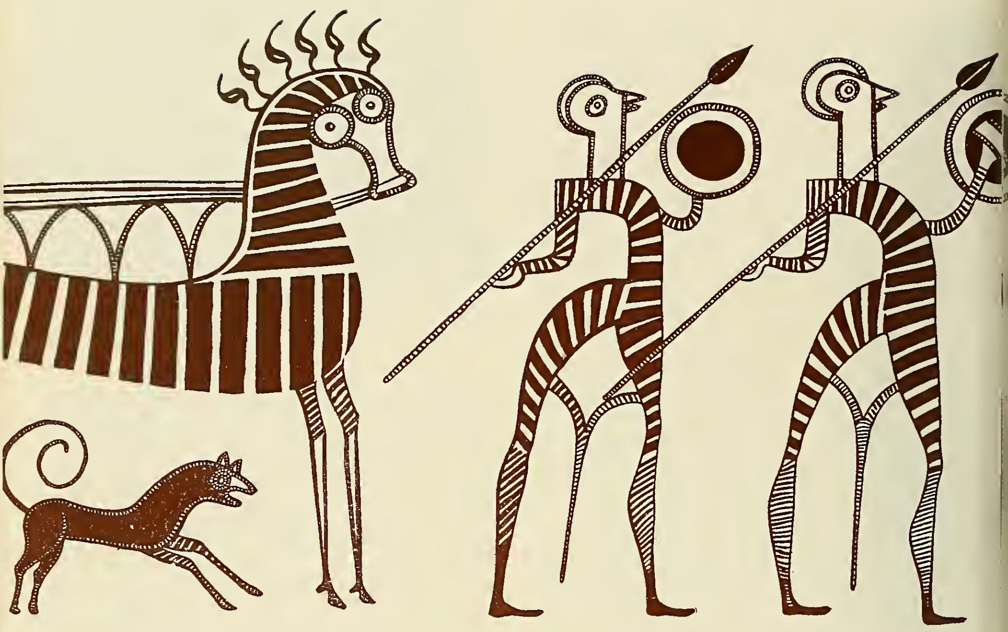
Almost all the clay tablets found at Knossos were in Linear B, and the total number of tablets now known—including, of course, many small fragments—is between three and four thousand. All these tablets apparently came from the palace (built in the period called by the archeologists Late Minoan II), which was destroyed by fire at the end of the fifteenth century B.C. It was this heat of destruction that served to bake many of the clay tablets to hardness and so made them durable. For, contrary to the usual



Deer hunt from chariot is another Mycenaean scene cut in a gem in intaglio. Both seals are in the Athens Museum.



Lion hunt on foot, *left*, is among the most celebrated of Mycenaean antiquities. Scene is inlaid in gold and silver on the blade of a bronze dagger and is shown here somewhat larger than true size. This is also at the Athens Museum.



Figures on Mycenaean pottery, in contrast to delicate metalwork and seal engravings, are crude. Seen above are

practice in Anatolia and farther east, the tablets in the Aegean area were never deliberately fired.

Up to 1939, Linear B *tablets* were known only from this one site in Crete. But a small number of vases had been found in mainland Greece having inscriptions that had been painted on them before they were fired. While these showed some variant forms, they had the same general appearance as Linear B. The presence of a Cretan script on the mainland was not surprising since, on Evans' theory of a Minoan Empire, Cretan imports might obviously be found at any site under Minoan control. But just before World War II the situation was dramatically reversed.

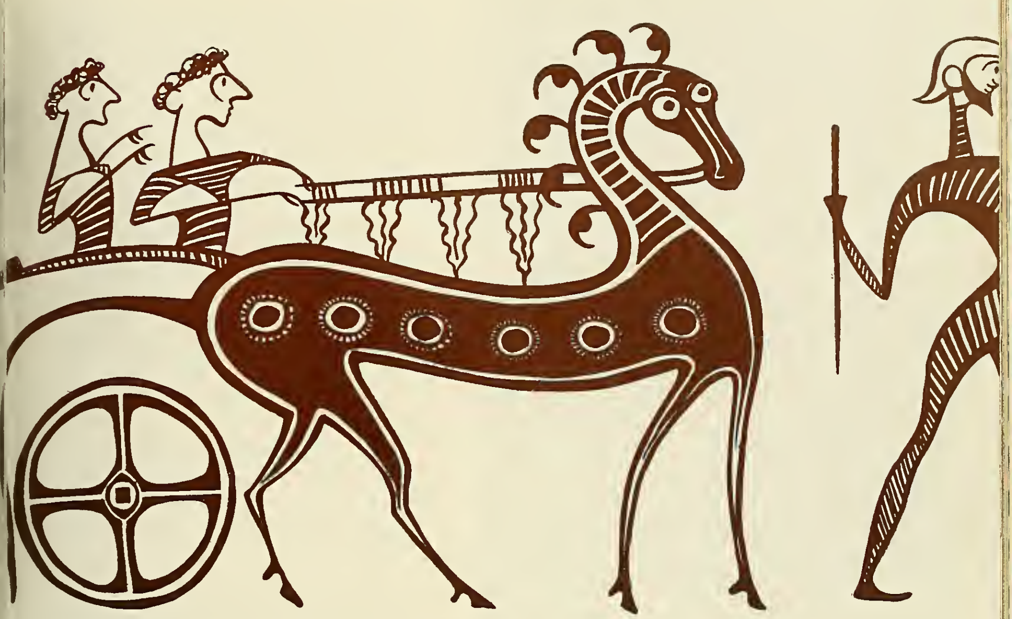
Schliemann had been led to Mycenae by believing in the truth of the Homeric legend. Could not other Homeric cities be located? This was the question in the mind of Professor Carl Blegen, then of the University of Cincinnati, one of the foremost experts on the prehistoric period in Greece, whose careful work on the site of Troy is justly famous. He set out now to find the palace of another Homeric monarch, Nestor, the garrulous old warrior whose name was a byword for longevity.

Nestor ruled at Pylos; but where was Pylos? Blegen found a likely site some four miles north of the bay of Navarino and, together with the Greek Dr. Kourouniotis, organized a joint American–Greek expedition to dig it in 1939. By an astonishing piece of luck, their first trial trench ran through what is now known as the archive room. Clay tablets were found within twenty-four hours; the first season's work produced no fewer than 600 of them—similar to the Knossos ones and written in the identical Linear B script. Then war intervened and the excavating could not resume until 1952, when more tablets were found.

To complete the history of the appearance of the texts, we may anticipate a bit to mention the discovery in 952 by Professor Wace of the first tablets from Mycenae. These were found not in the royal palace, which had been dug by Schliemann and Tsoundas at the end of the last century, but in separate buildings or houses outside the walls of the acropolis, or royal castle. A further find in 1954 brought the number of tablets from this site up to fifty.

Professor Emmett Bennett, who has now become the world expert on the reading of Mycenaean texts, had already established the different systems of weights and measures in Linear A and Linear B. But his outstanding contribution, working on Blegen's Pylos finds, was the establishment of a signary—the recognition of variant forms and the distinction of separate signs. How difficul such a task is only those who have tried can tell. It is eas enough for us to recognize the same letter in our alphabe as written by half a dozen different people, despite the us of variant forms. But if one does not know what is the possible range of letters, or the sound of the words they spell it is impossible to be sure if some of the rare ones ar separate letters or mere variants.

This is still the position with regard to Linear B. It is t Bennett's credit that so few such problems now remain



foot soldiers, charioteers, horses, and a dog, as rendered on pottery bowls in the collection at the Athens Museum.

diligent comparison enabled him to set up a table of variants that made it clear—in the case of all but the rarest signs—what was the possible range of variation. At this time the remarkable and gifted young man who is the central figure of our detective story, Michael Ventris, was already exchanging ideas with Bennett. Their correspondence laid the foundation of a friendship, which developed during Bennett's visits to Europe.

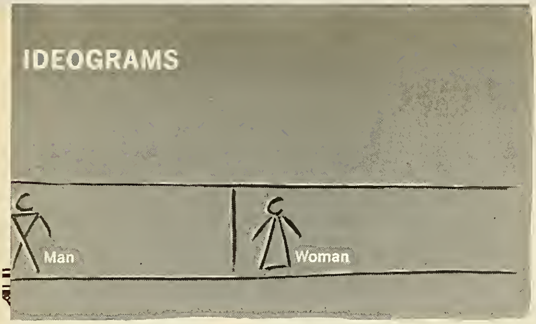
With Bennett's publication of *The Pylos Tablets*, in 1951, the scene was set for the decipherment of Linear B. Orderly analysis, begun by Bennett and another American expert in this field, the late Dr. Alice Kober, could now take the place of speculation and guesswork. But it required clear judgment to perceive the right methods, concentration to plod through the laborious analysis, perseverance to carry on despite meager gains, and the spark of genius to grasp the right solution, when, at last, it emerged from the painstaking manipulation of meaningless signs. These admirable qualities were to be provided in full measure by Michael Ventris.

The Linear B texts consist of groups of signs separated by vertical bars: the length of the groups varies from two to eight signs. Accompanying these, in many cases, are other signs that stand alone followed by a numeral: many of these are recognizable pictograms. It is easy to guess that single signs, standing alone, are probably ideographic, that is, representing a whole word. Those used in groups are likely to be either syllabic or alphabetic. A count of all these signs shows that they number about eighty-nine—the exact total is still disputed. But even this uncertain number is significant: it is far too small for a wholly ideographic system, and it is much too large for an alphabet. Linear B must therefore be syllabic—and a fairly simple form of syllabary, like the Cypriot or the Japanese Hiragana system.

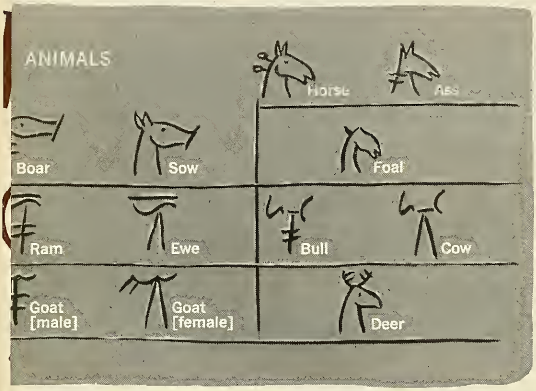
The numerals in Linear B are straightforward; they were tabulated by Evans at an early stage. They are based on the decimal system, but are not positional; there is no notation for zero, and figures up to 9 are represented by repeating the sign the appropriate number of times, much as in Roman numerals. Vertical strokes denote digits, horizontal strokes tens, circles hundreds, circles with rays thousands, and circles with rays and a central bar tens of thousands. Thus 12,345 is written 𐄫𐄣𐄛𐄓𐄋.

The basis of the Mycenaean system of measures, in turn, had been worked out by Bennett in 1950. He showed that the signs 𐄷, 𐄸, 𐄹, 𐄺, etc., constituted a system of weights, while other goods were recorded in the series 𐄼, 𐄾, 𐄿 or 𐄽, 𐄾, 𐄿. As Bennett correctly guessed, the former series was used for dry measure, the latter for liquids. The use of the same symbols for the lower fractions is paralleled by the English use of *pint* and *quart* for both dry and liquid measure, the series thereafter diverging to the separate categories of *bushel* and *gallon*.

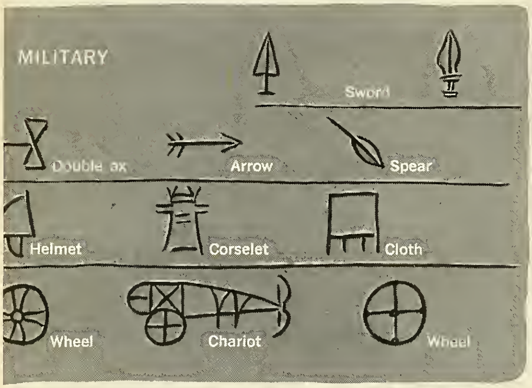
With this knowledge, the signs on the tablets then could be divided into their two classes: ideograms (together with metric signs and numerals) and syllabic signs.



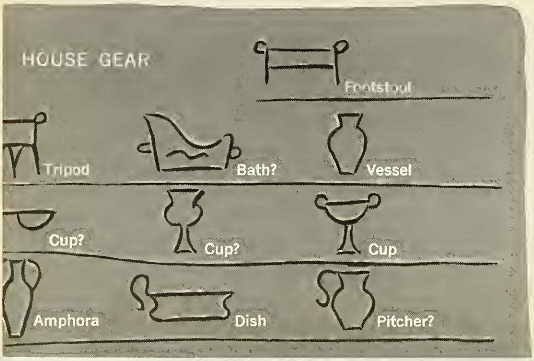
IDEOGRAMS



ANIMALS



MILITARY



HOUSE GEAR

The meaning of some of the ideograms was obvious, bu there were many signs too stylized to allow guesswork. was, however, possible to classify many more of the ide grams with the help of those that could be recognize Thus, along with horse, , and pig, , were regularl found three other ideograms, which were therefore likel to belong to the same category of livestock. It was als noticed that variants of the livestock ideograms occurre the commonest being to modify the main vertical stroke axis of the sign by adding two short crossbars, or dividir it into a fork. Evans had correctly guessed that these var ations signified male and female animals.

Thus, in many cases, it was possible to deduce the ge eral subject matter of the tablets before a single syllab could be read. Almost without exception, it was clear th they were lists, inventories, or catalogues. For instance, list of single sign groups (word), each followed by t ideogram for man, , and the numeral 1, was clearly list of men's names, a muster roll or the like. On the oth hand, where a word was followed by the word man and number larger than one, and this collocation was repeat on a number of different tablets, the word was likely to a descriptive title or occupational term, like cowherd tailors, or men of Phaistos.

This method of deduction, since it depends chiefly studying the same words in different combinations, is oft called combinatory. It leads to valuable conclusions abo the meaning or sort of meaning possessed by certain wor At a later stage, these conclusions can act as a check o correctness of a decipherment, because they are compl independent of the syllabic values. For example, if a so identified as an occupational term turns out, when t scribed phonetically, to mean cowherds, this lends weig to the phonetic interpretation.

As this is largely the story of Michael Ventris' achie ments, it will not be out of place here to give a sh account of his life. He was born on July 12, 1922, of a we to-do English family. He went to school in Switzerlan early discovering a remarkable ability to learn languag quickly and by ear. Later, he attended the Architectu Association School in London, flew as a bomber navigat with the R.A.F., and received his architecture diploma 1948. From an early period in his life, he had been fas nated by the Minoan scripts. This interest he never lo with rare concentration, he devoted much of his spare ti to painstaking studies of the problems they present Ventris' remarkable mind made him able to disce among the bewildering variety of mysterious signs, p terns and regularities that betray the underlying structu

CRYPTOGRAPHY is a science of deduction and controll experiment; hypotheses are formed, tested, and oft discarded. But the residue that passes the test grows a grows until finally there comes a point when the expe menter feels solid ground beneath his feet: his hypothe cohere, and fragments of sense emerge from their cam flage. The code "breaks." In June, 1952, Ventris felt t Linear B had broken. As he transcribed more and m texts, so words began to emerge in greater numbers; n signs could now be identified by recognizing a word which one sign only was a blank, and this value could t be tested elsewhere. The spelling rules received confir tion, and the pattern of the decipherment became clear.

At this moment, Ventris was asked by the B.B.C. to g

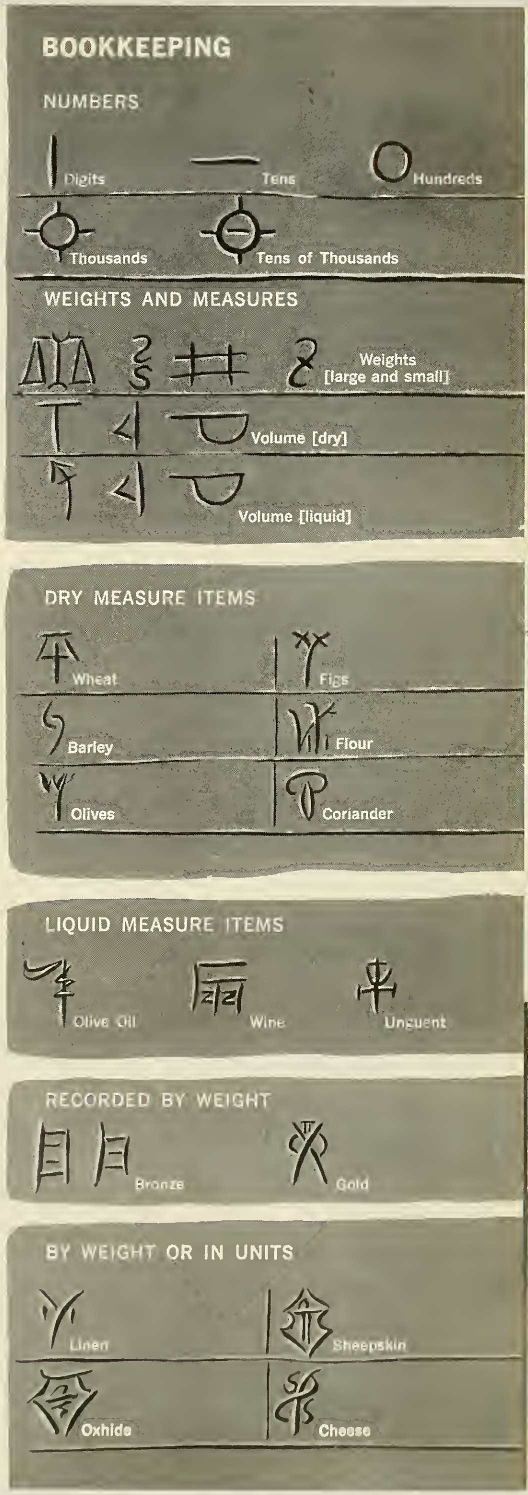
alk on the Third Programme in connection with the pub-
ation of *Scripta Minoa II*, the volume on Linear B that
ans had begun before his death and that his friend the
ssics scholar Sir John Myres had undertaken to com-
te. Ventris determined to take this opportunity to make
discovery public. Thus, at the conclusion of his radio
dress, came the astonishing announcement: "During the
t few weeks, I have come to the conclusion that the
ossos and Pylos tablets must, after all, be written in
eek—a difficult and archaic Greek, seeing that it is five
ndred years older than Homer and written in a rather
breviated form, but Greek, nevertheless."

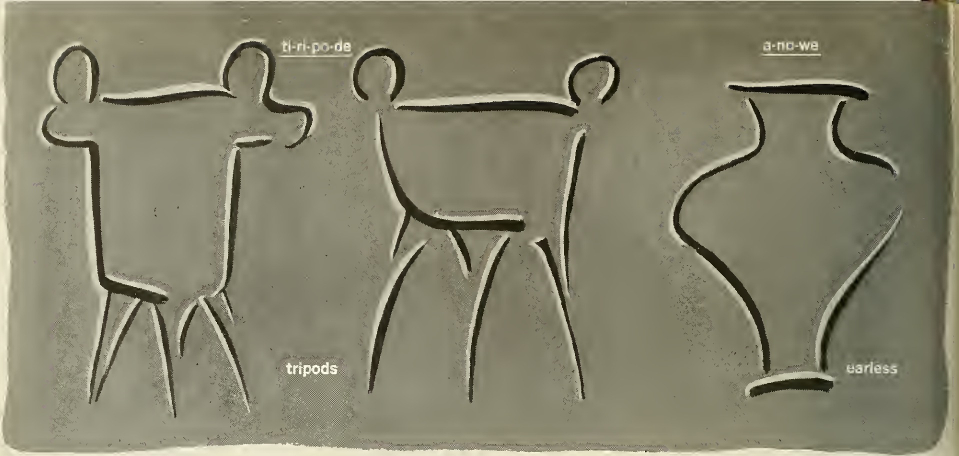
Ventris went on to quote four well-known Greek words
at he claimed to have found in Linear B: *poimén*, shep-
rd; *kerameus*, potter; *khalkeus*, bronzesmith; *khrus-
orgos*, goldsmith. He ended on a suitably cautious note:
have suggested that there is now a better chance of read-
; these earliest European inscriptions than ever before,
t there is evidently a great deal more work to do before
are all agreed on the solution of the problem." I do not
nk it can be said that this broadcast made a great im-
ession but I, for one, was an eager listener. The word
rusoworgos, in particular, was encouraging. W did not
st in most forms of Greek of the classical period, but
uld certainly appear in an archaic dialect, since its loss,
in Homer, was known to be recent. Eager to try out the
ory, I set to work with words from two sets of texts.

four days, I had convinced myself that Ventris' iden-
fications were in the main sound. I collected a list of
ty-three plausible Greek words I had found in the
ets (some of which had not then been noted by Ven-
s) and wrote to Ventris, congratulating him on having
und the solution, and putting forward a number of new
ggestions. The next thing Ventris did was to draw up a
of words for which plausible Greek equivalents could
suggested. This "Experimental Vocabulary" contained
3 entries (including proper names). A very few of these
now recognize to be wrong and a few more have been
dified but in the main the Greek words here provided
ound foundation on which we could build.

Even before Ventris' theory could be published, Pro-
sor Blegen—the excavator of Pylos—put into our hands
lecisive confirmation in full-dress form. One afternoon
May, 1953, Ventris called me from London in a state of
eat excitement—he rarely showed signs of emotion, but
him this was a dramatic moment. The cause was a letter
om Professor Blegen. He had found more tablets in 1952.
t no one had yet examined them carefully; they had
en cleaned during the winter and only the next spring
re they ready for study.

Blegen's letter ran: "Since my return to Greece I have
nt much of my time working on the tablets from Pylos,
tting them properly ready to be photographed. I have
ed your experimental syllabary on some of them. En-
sed for your information is a copy of P641, which you
y find interesting. It evidently deals with pots, some on
ee legs, some with four handles, some with three, and
ers without handles. The first word by your system
ms to be *ti-ri-po-de* and it recurs twice as *ti-ri-po*
ingular?). The four-handled pot is preceded by *qe-to-
-we*, the three-handled by *ti-ri-o-we* or *ti-ri-jo-we*, the
ndleless pot by *a-no-we*. All this seems too good to be true.
coincidence excluded?"





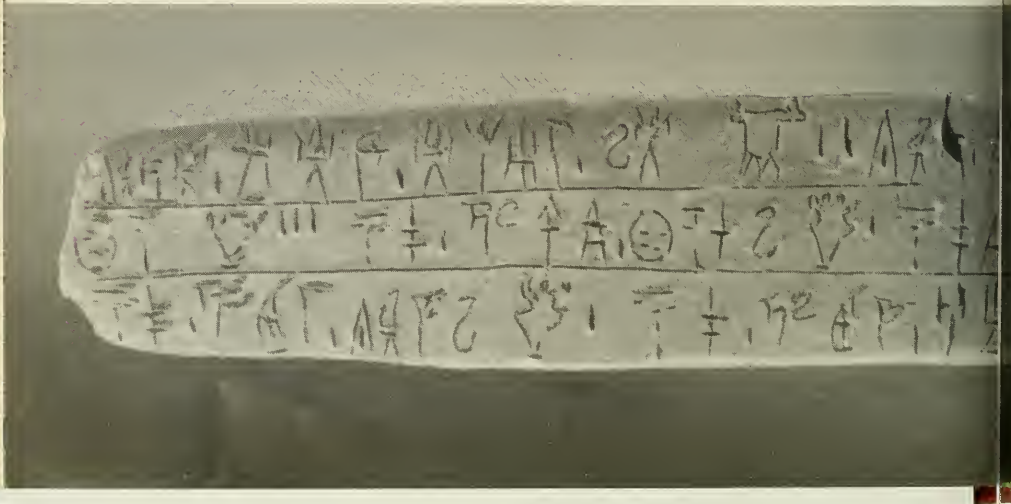
The interpretation of some phrases in this tablet is still disputed, but Blegen's analysis of its contents from the ideograms is evident, and the relative words are clear. Where there are pictures of tripod-caldrons, we have the word *ti-ri-po* (that is *tripos*, which means tripod). Then follow the adjectives, which vary with the number of handles. The second term of the compound is always *-o-we* (that is, *-owes*, or *-oues*, which means ear). This is the word regularly used in Greek for the handles of a pot: Nestor's cup had four ears. The first part consists of *tri-* (as in *tripos), for three; q^uetro-*, for four; and *an-* (the negative prefix), for no handles.

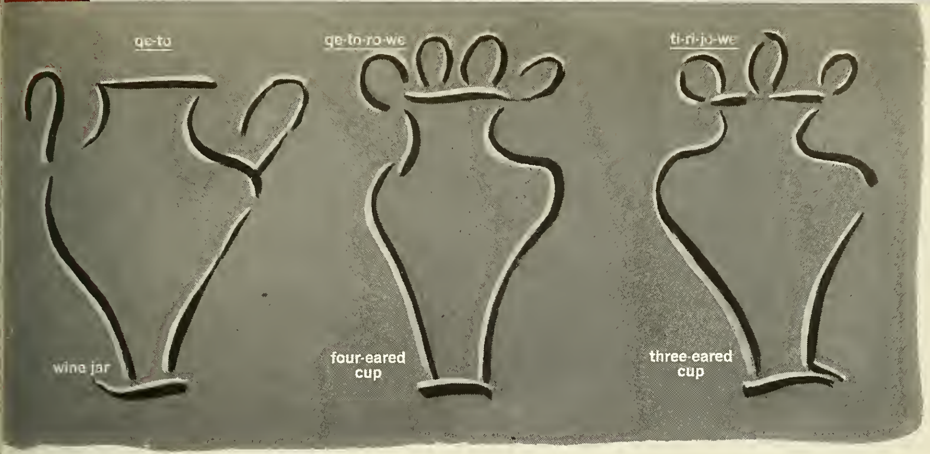
The odds against getting this astonishing agreement purely by accident are astronomical: this was a proof of the undeniable correctness of Ventris' decipherment. All who were unprejudiced could now be convinced that the system worked; further refinements would no doubt be possible, but the basis was obviously sound.

Another equally improbable case of coincidence followed, for which I can claim a small share of credit. In the spring of 1955, Dr. Platon, Director of the Iraklion Museum, told me that he had found in the museum storerooms some trays containing fragments of tablets; they had been exposed to the weather when the museum was damaged during the war, and he thought they would be useless. They were certainly in a poor way; but one largish piece was the left-hand end of a two-line tablet; the break showed plainly half a horse's head—the ideographic sign for "horse." Now, horses appear in the Knossos tablets only in the records of the chariot force, which have a quite different form, and in one isolated tablet showing horses and foals—a famous tablet that Evans had published. The left-hand edge of that tablet was missing: this seemed to be it. We now had the introductory words for each line, and they read, by Ventris' system: *i-qo*, horses; and *o-no*, asses. Again Blegen's question could be asked: is coincidence excluded? What are the chances that two series of equine heads will be introduced by words exactly corresponding to the Greek for horses and asses? Such probabilities are beyond calculation; we can only use common sense.

The most exciting prospect now was that of reading al the new Pylos tablets found in 1952. Ventris invited me t

KEY TABLET, confirming Ventris' decipherment, is this one found by Blegen at Pylos in 1952, but not examined until





are the task. and our collaboration enabled us to comete the work in a matter of twelve months or so. *Docuents in Mycenaean Greek* was completed in the summer 1955 and published in the autumn of the next year.

In April, 1956, the French Centre National de Reerche Scientifique, under the direction of Professors iantraine and Lejeune, organized the first International olloquium on the Mycenaean texts. Nine French and even foreign scholars from seven countries met for a eek near Paris, to discuss the work done and to plan for e future. At this meeting Ventris was, of course, the leadg figure; his fluency in French made a great impression, ut he was equally at home chatting to the Swiss in Schwyrdeutsch, or to the Greek delegate in Greek.

Five months later he was dead—killed in a tragic autoobile accident—but the work Ventris did lives, and his ıme will be remembered so long as the ancient Greek nguage and civilization are studied.

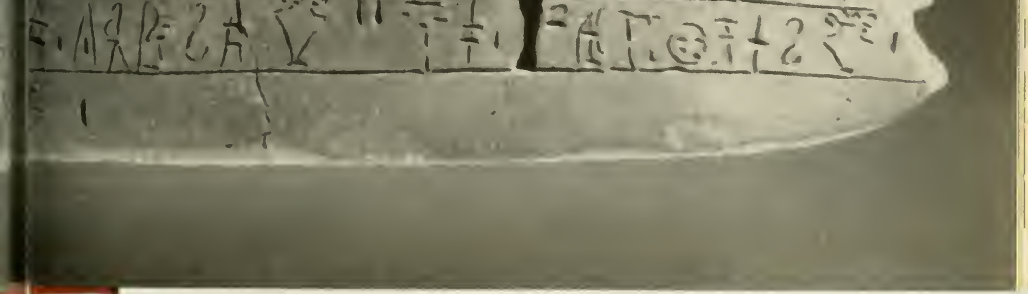
There still remain a number of the rarer signs in Linear whose values are not yet established. and the texts that e completely intelligible are few. Yet we may now read, for example: PU-RO *i-je-re-ja do-e-ra e-ne-ka ku-ru-so-jo i-je-ro-jo* women 14 [In translation: At Pylos: slaves of the priestess on account of sacred gold: 14 women.]

But the mere fact of being able to translate the tablet does not automatically answer all questions. Why were these women slaves of the priestess? Which priestess? What was the sacred gold? What was the state of affairs or the transaction that this tablet was meant to record? These are questions that we cannot answer; the facts were known to the writer of the tablet. and he did not expect it to be read by anyone lacking the same knowledge.

This problem is still with us, and will always remain: we cannot know all the facts and events of which the tablets are an only partial record. We have to examine them minutely, compare them with similar documents elsewhere, and check them against the archeological evidence. Imagination may help to fill in the gaps. and I shall attempt to look beyond the bare texts at life in the Mycenaean world; but it is no good pretending we know more than we do.

[*To be concluded in April*]

e following year. In this inventory of various vessels, entris' sign values yielded the Greek words shown above.



Plumes, Threats, and White Beauty

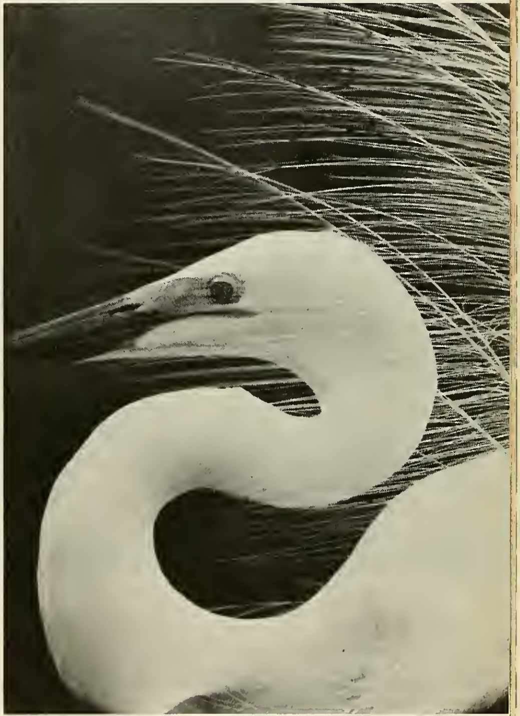
he courtship displays of herons are fascinating spectacles

By ANDREW J. MEYERRIECKS

WATCHING HERONS can be profitable. It may be undertaken for the simple enjoyment a bird watcher de- ves from the sight of a graceful egret methodically stalk- g its prey on a broad marsh, for the photographic record patient cameraman may compile of the activity in a owded heronry, or for insights into the origin and evolu- on of complex behavior during courtship that serious bi- logists may discover while comparing related species.

Some sixty-three species of herons, egrets, and bitterns ake up the Family Ardeidae; thus, a variety of forms are vailable for comparison—a powerful tool for the behav- rist. More species make for more firmly based theorizing. ome species of herons are almost cosmopolitan in their reeding distributions, and such a broad range is an asset studies of the geographical variation of behavior. These ay disclose, for example, whether populations of com- on or great egrets, *Casmerodius albus*, in Florida Bay, urope, Africa, and Japan—where Tokutaro Tanaka took e unique photographs on these pages—behave exactly like. The study of heron sociality is aided by the diver- ty of social structures found among various species: a few re solitary, some are social only during the nesting season, nd many are social in most of their activities. *C. albus*, for xample, tends to be solitary outside the breeding season, ut it nests in small to large colonies, often alongside other ecies of herons and egrets. The question is: how has such social structure evolved?

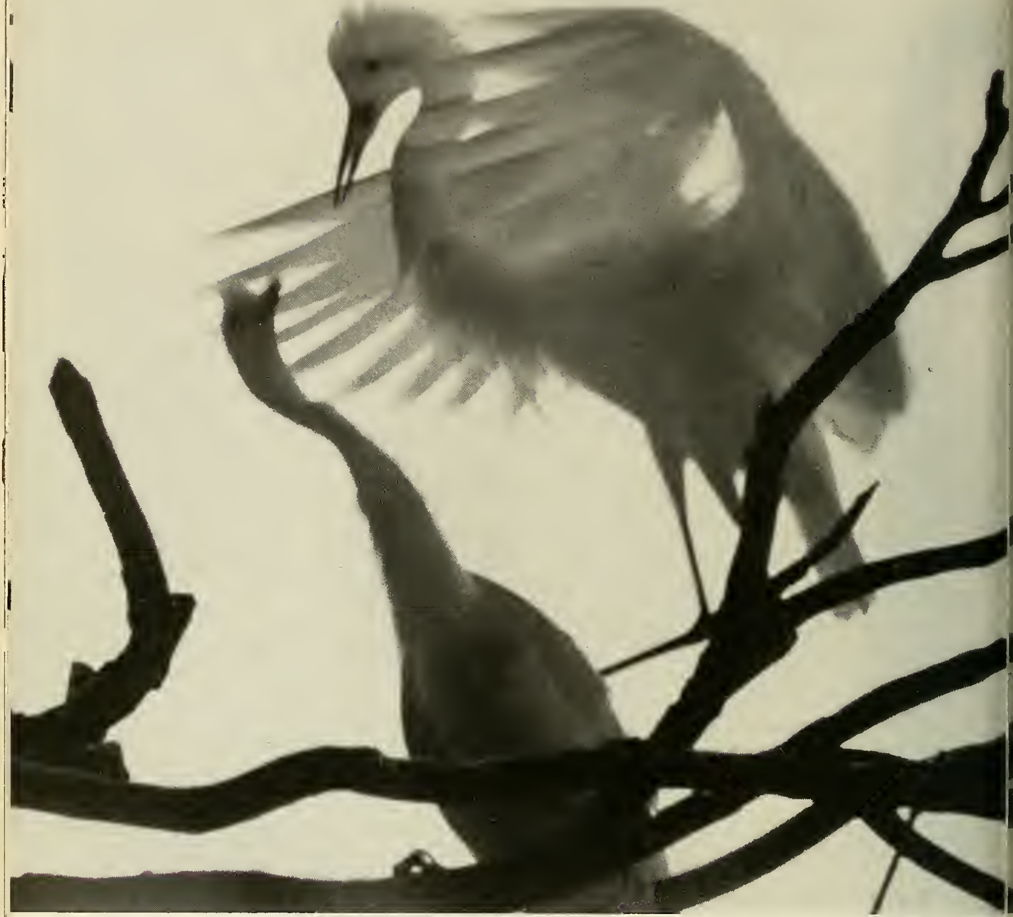
To many, the word heron evokes the image of a slender, raceful bird, perhaps awaiting its prey while standing mo- onless at the edge of a stream or pond, or slowly working s way through the shallows, its dagger-like bill poised for strike. But herons show a fascinating array of feeding ethods, ranging from the erratic dashes of the reddish gret to the open-winged whirling of the Louisiana heron. ome, like our own snowy egret or the little egret of the ld World, rake the muddy bottom of their feeding area, us forcing their aquatic prey to reveal their hiding places. thers, notably the cattle egret, have left the ancestral ater habitat to associate with hoofed mammals and other beaters" in order to secure food (NATURAL HISTORY, ugust-September, 1960). How these diverse methods of eding behavior have evolved and the role they play in heron ecology are fertile areas for intensive investigation.



EGRET'S PROFILE shows nuptial plumes and lore, the area in front of eye. The lore gains color at start of nesting season.

ptial plumes of great egret male in a Japanese heronry e much in evidence at the beginning of breeding season.

The taxonomist is interested in the many color patterns shown by herons and allied species: some, like *C. albus*, are pure white, others are predominantly dark-colored, and some are heavily striped, blending with the vertical reeds and cattails of their environment. A few are of special interest because they are found in several colors—or phases—regardless of age or sex. A pure white bird, for example, may mate with a dark-colored individual of the

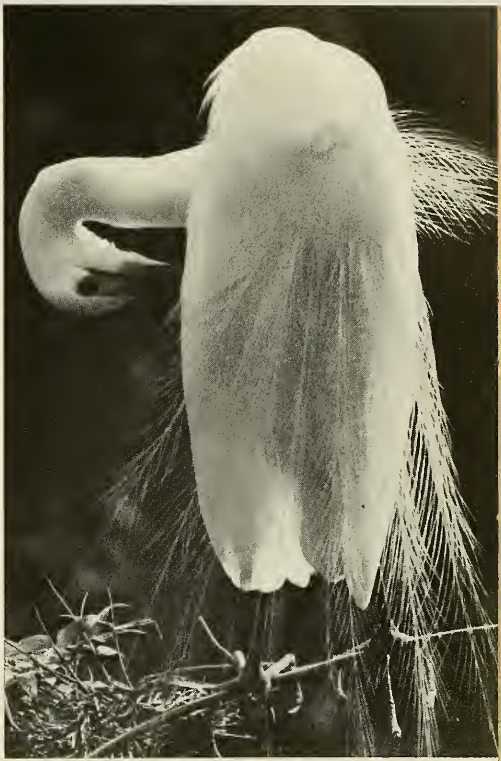


FLAILING WINGS and outstretched neck are part of hostile postures of intermediate egrets, *Egretta intermedia,* in a Japanese heronry. Threats and fights between the birds ar common in crowded heronry at start of the nesting perio

same species. Such color phases have diverse meanings and are inherited in various ways (NATURAL HISTORY, January, 1958). The study of herons offers many chances to examine these questions and others of general biological import.

But it is during the breeding season that herons delight the eyes of the inveterate heron watcher, offer superb opportunities to the photographer, and give the student of heron behavior his most exciting moments. At this time, herons acquire a distinctive nuptial plumage, show marked changes in the color of their soft parts, and exhibit a host of specialized displays confined to this stage of their annual cycle. No two species of herons have exactly the same kind, number, and placement of their special, breeding season plumes. Long white crown plumes are worn by species such as the black-crowned night heron.

MUTUAL BILLING (shown above and in photos at right) amon great egrets occurs after male lets female enter the nes



Decomposed plumes of breeding season trail down back of egret. The birds once were widely hunted for these feathers.

while others display an array of slender, decomposed feathers on their backs—the prized egret plumes of the feather trade. Even the somber American bittern male exhibits white. fan-shaped feather patches during courtship.

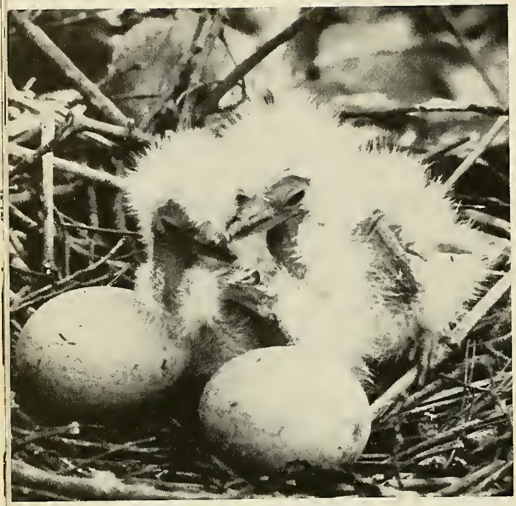
Whether bearing a train of superb back plumes or a mere tuft of crest feathers. each species uses its specialized nuptial adornment in a number of displays confined to the courtship period. In species whose breeding biology is known in some detail, the sequence of events is roughly comparable. At first. the male adopts a territory located in a traditional breeding area. Here he proclaims ownership by advertising his presence physically and vocally. During the day, the male patrols his section of the colony, calling loudly and frequently from a number of advertising posts. Often this call differs from the normal notes of the species, although it may resemble an alarm or warning call heard throughout the year. The territory-holding male also attracts attention by virtue of his fully developed plumage, brilliant soft part coloration, and great activity.

The male defends his initial territory vigorously: when a trespasser appears. his first response is usually a low-intensity threat display. This demonstrates one of the two main functions of the specialized plumes. The owner fairly bristles, and his apparent size is increased greatly by the erection of various feather tracts—but mainly of his nuptial plumes. If the intruder does not leave, the owner erects his feathers to an extreme and moves to attack. This normally suffices to make the trespasser retreat but, if not, the owner drives his opponent, male or female, from his display area. If the intruder is a female. however. she will persist, returning repeatedly to a particular male's domain. Eventually. the male shows a change in his behavior. The female will be allowed to remain on the edge of his territory while he begins to perform a number of displays not previously seen. This is the second major function of the nuptial plumes: they greatly emphasize the movement of different body parts during the male's performance. There is a neat correlation between the type of plumes. their location, and the part of the body being moved.

Up to this time. the male will have kept the female from entering the nest he has started to build. or at least from the site of the future nest. Furthermore, his displays have been vocal and visual. But soon the male permits the female to approach within touching distance. and now they may engage in mutual contact displays. This is a period of tension, for the male has allowed another heron, even though it is his prospective mate, to enter that part of his territory most vigorously defended—the nest. Tension is relieved, apparently, by mutual feather nibbling and billing. One bird will run its bill through the plumage of the other very cautiously, then its mate will reciprocate. Often the two herons, will face each other and snap their mandi-

Interplay of bills, and feather nibbling, seem to help relieve male's tension at allowing another bird into nest.

Displays continue even after pair has formed, and may be performed when a mate returns to nest after brief absence.



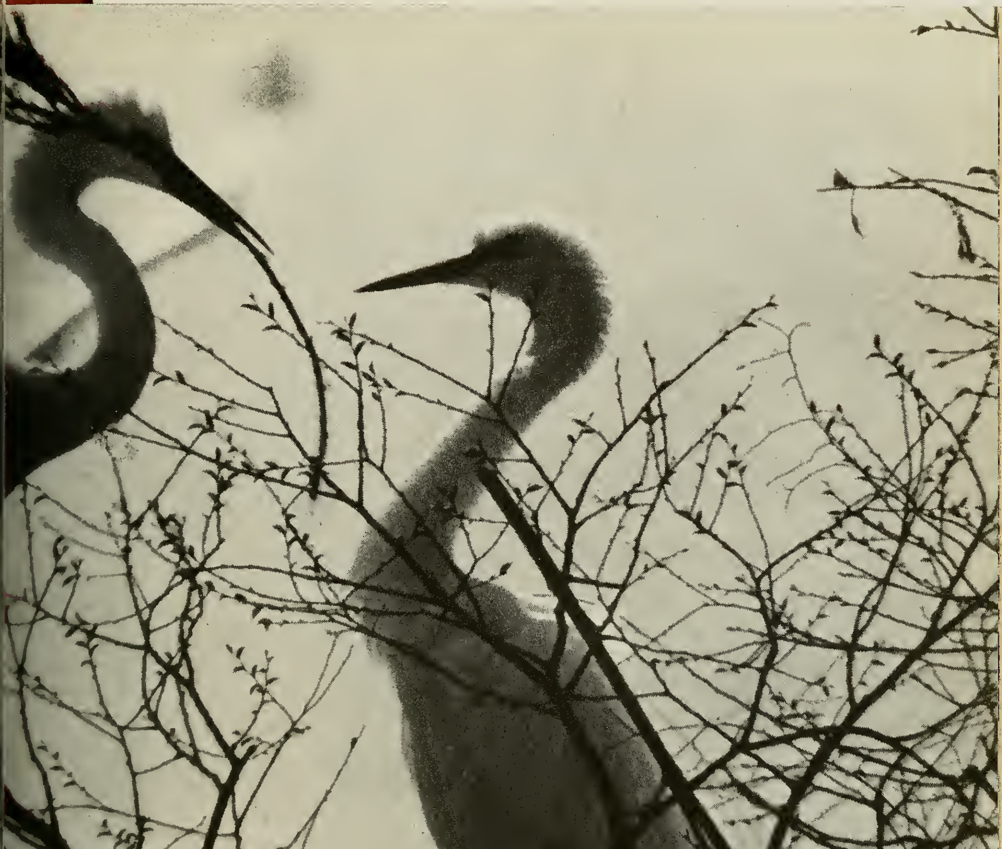
Nestlings and eggs are seen in nest in heronry. Nuptial displays of parents may occur even when young are in nest.

bles together rapidly, or even nibble at each other's bill. Shortly after the pair has formed, such mutual displays are performed on the return of either mate to the nest after a trip to gather nest twigs, or even after a feeding absence. In some species, such mutual behavior may involve an elaborate display of the specialized nuptial plumes as well as billing and nibbling. Indeed, such use of the nuptial plumage may last for the rest of the breeding cycle, although this is not true for all species.

It is clear that the specialized calls, colors, and plumes have evolved to serve a number of functions effecting pair formation and related behavior, for these traits largely disappear during the rest of the year. In fact, as noted, individuals of many species even avoid one another outside the breeding season, and conspicuousness would be a definite disadvantage for them. True, a brilliantly colored male, loudly proclaiming his presence in the breeding colony in order to establish a territory and secure a mate, is vulnerable to predation. But the needs of species continuity and individual safety are balanced in the course of evolution by varying compromises. Vulnerability via prominent advertisement may be offset by social nesting habits, increased aggressiveness, and the like.

We know partial answers to some questions concerning heron biology, but as is so true in science, partial answers often lead to new questions of even greater importance. Of the sixty-three or so known heron species, only fragmentary information on a few species is currently available. The study of herons is highly recommended therefore, to bird watchers, photographers, and biologists alike.

Dr. Meyerriecks, whose works have appeared previously in Natural History, has specialized in heron research and is with the Massachusetts Audubon Society. The unusual photographs on these pages were taken by Mr. Tanaka, an amateur photographer since 1932 and lifelong nature lover.



AIR OF EGRETS show ruffled feathers on crest and neck uring the early stage of nest building, which is also a tense period for male. Relaxation of tension by means of displays leads to synchronization of the pair's activities.

Fox Writers of Sanga

East of the Niger River, answers to questions are read in sand

By Curtis Reider

At the rim of the Bandiagara Escarpment in the French Sudan, some ninety miles east of the Niger River port of Mopti, are nine small, mud hut villages, within calling distance of each other, that comprise the community of Sanga.

To one who looks upward from the Séno Plain—which here lies more than five hundred feet below the escarpment's top—the mud villages seem perfectly isolated. Indeed, the one passageway between Sanga and the lower country is a narrow, twisting crevice that breaks the face of a natural, fortress wall. Through this defile, only one person may pass at a time.

The people of Sanga are Dogons. Each village possesses a language o its own. Other languages of intercommunication among inhabitants of th nine villages are the common tongu of Dogon, and Bombari, the lingu franca of this part of Africa.

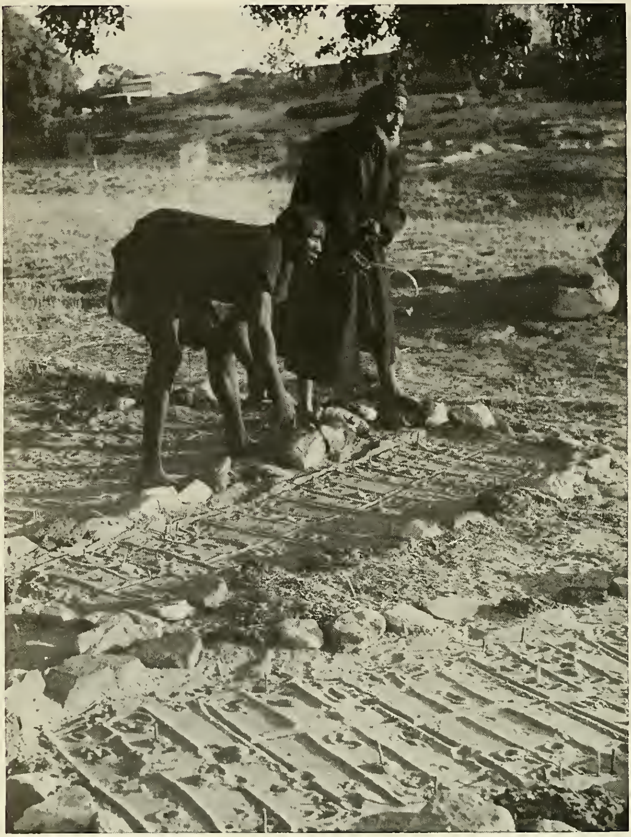
Essentially, the Dogons are farmers: despite their exotic location, th prosaic onion is their principal commercial crop. Each village maintain its onion beds, surrounded by wove cane fences to keep out domestic animals. Women tend the onion field from morning until night, carrying o their heads earthenware jugs of wate to supply them during their day' work in the blazing sun.

When the crop is harvested, th women pound the onions to a pulp using wooden clubs and singing i cadence as they work. The pulp i then dried in the sun, and carried th ninety long miles to Mopti to b traded for dried fish. Fish, togethe with fowl and goat, constitutes th chief source of protein of the peopl of the Sudan and the Haute-Volta.

Social stratification in the village of Sanga is strongly defined Ranking next to the chief in each village is the blacksmith, followed by th carpenters. The children of these social leaders may not marry into th farm families, for this would be beneath their rank in the society.

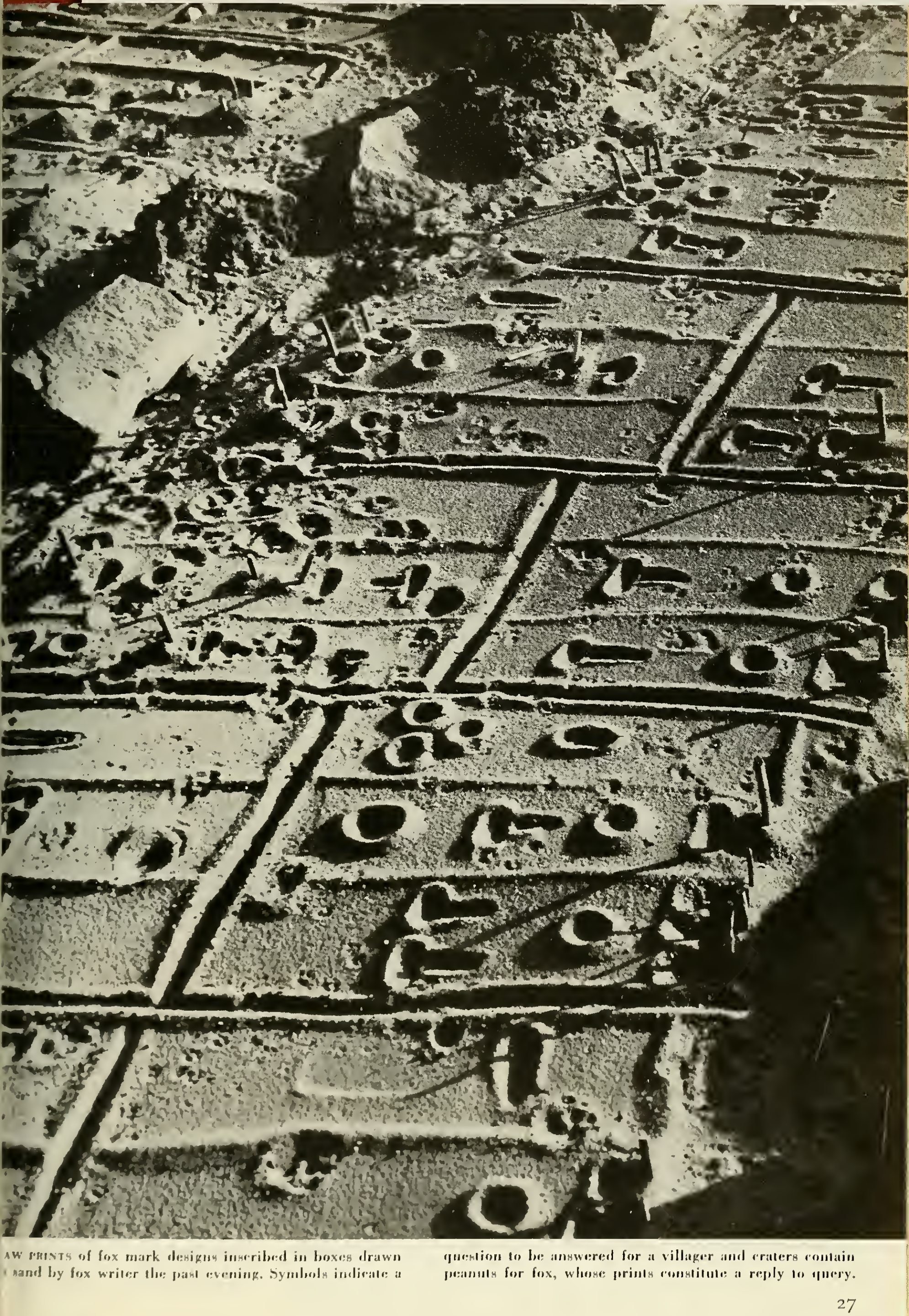
Blacksmiths, whose craftsmanshi is noteworthy, are highly respecte both as artisans and as accomplishe sorcerers. Using only files and th simplest raw materials, Dogon blacksmiths produce muzzle-loading flin locks that, although not weapons c great accuracy, are true works of ar They also produce farm implement and all metal tools used in the village

While each village has its own fetish chief, who resolves such question

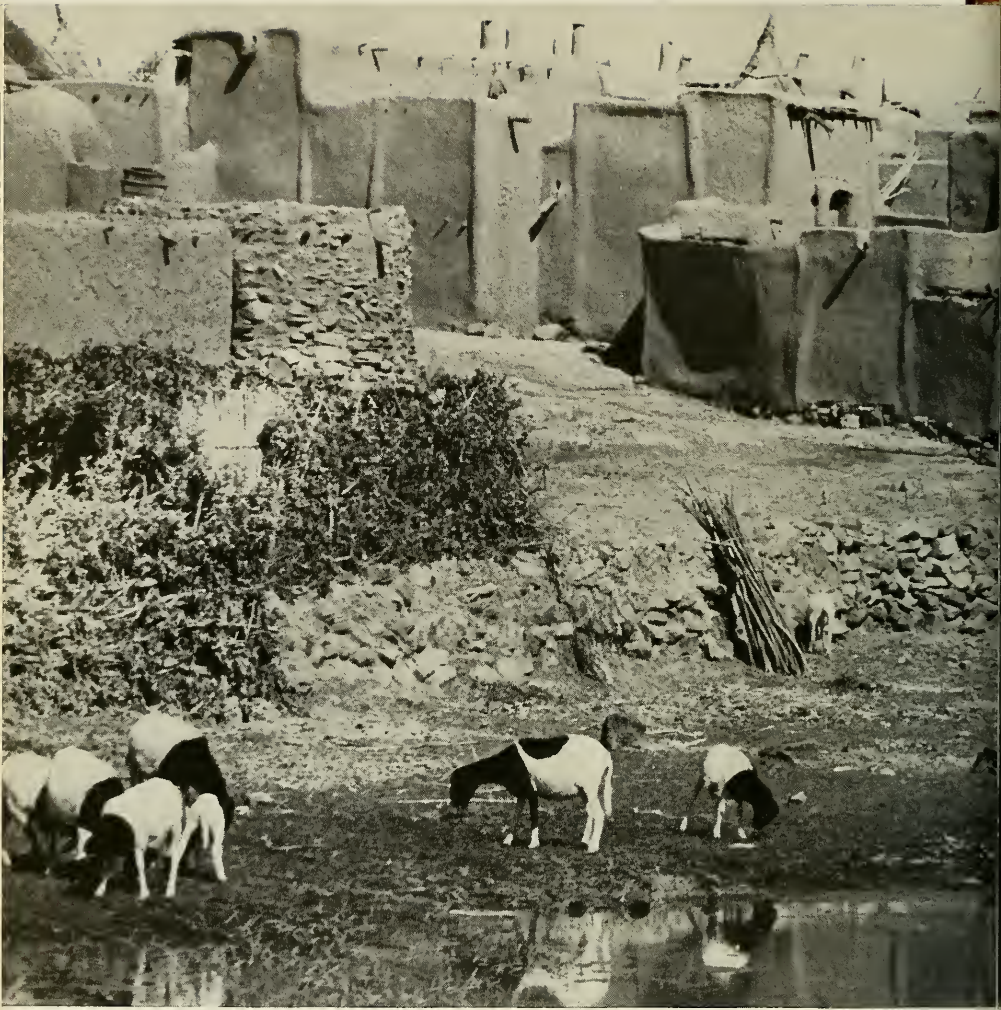


Fox writer, an aged Sanga villager, interprets traces left in the sand by "ghost fox" as the man stooping beside him awaits answer to questions posed.

Mr. Reider, who has traveled widely through Africa during recent years, is a free-lance writer and photographer.



AW PRINTS of fox mark designs inscribed in boxes drawn sand by fox writer the past evening. Symbols indicate a question to be answered for a villager and craters contain peanuts for fox, whose prints constitute a reply to query.



MUD HUT VILLAGE is one of nine comprising the community of Sanga, set atop the Bandiagara Escarpment, more than five hundred feet above Séno Plain in French Sudan. Th people are Dogons, and the goat is chief domestic anima

as proper planting and harvesting times. there is also a rigid code of customs that governs life in the villages of Sanga. For example, anyone who causes the death of another person, however accidentally, is punished by permanent exile from the village. He must live outside the Dolo, or cluster of Dogon houses, that is his parent community. His family, by gifts of grain and goats, can regain status, but none of its members may ever speak to the exile again. Such exile, for people as gregarious as the Dogons, is worse than death, and the outcome is often suicide performed by leaping from the escarpment.

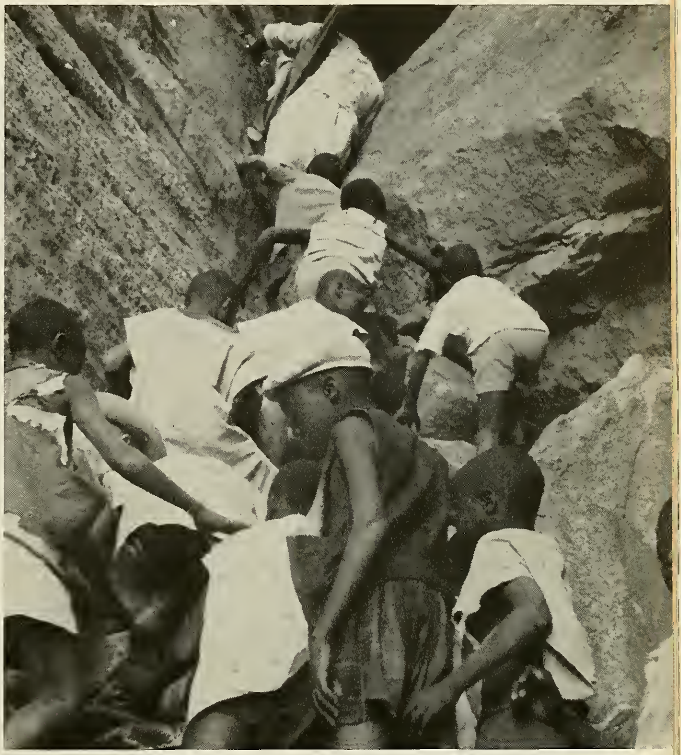
Among the most intriguing customs of the Dogons is the curious daily ritual of the "fox writers." Long ago, according to Dogon legend, a wise fox came every night to stand in the center of a circle of village elders and fetish chiefs. The old men would ask questions of the fox, who, being conversant with the Dogon language, would provide them with answers.

THE fox knew all things. He knew when to sow and when to reap, which wives a man should pick, how many sons they would bear him, and how many goats a father should r quest for the hand of his daughter.

One fateful night, after man months of famine, a hunger-craze villager killed the wise fox and a him. However, the fox's spirit su vived, so the legend says, although th ghost fox would never again speak the old men of the village. But in r turn for food, the ghost will still gi silent answers to their questions.

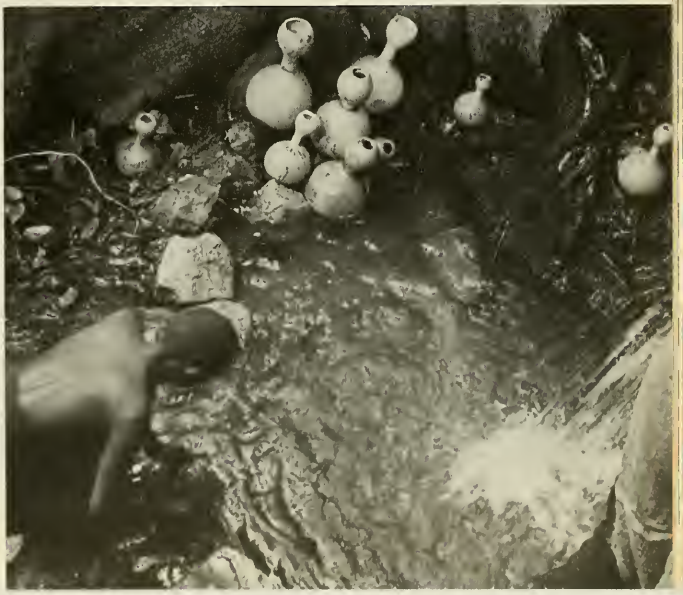
Each evening, one or two old me leave their respective villages and r pair to a large tree near the site of tl present Christian mission buildir in Sanga. The fox writers, who

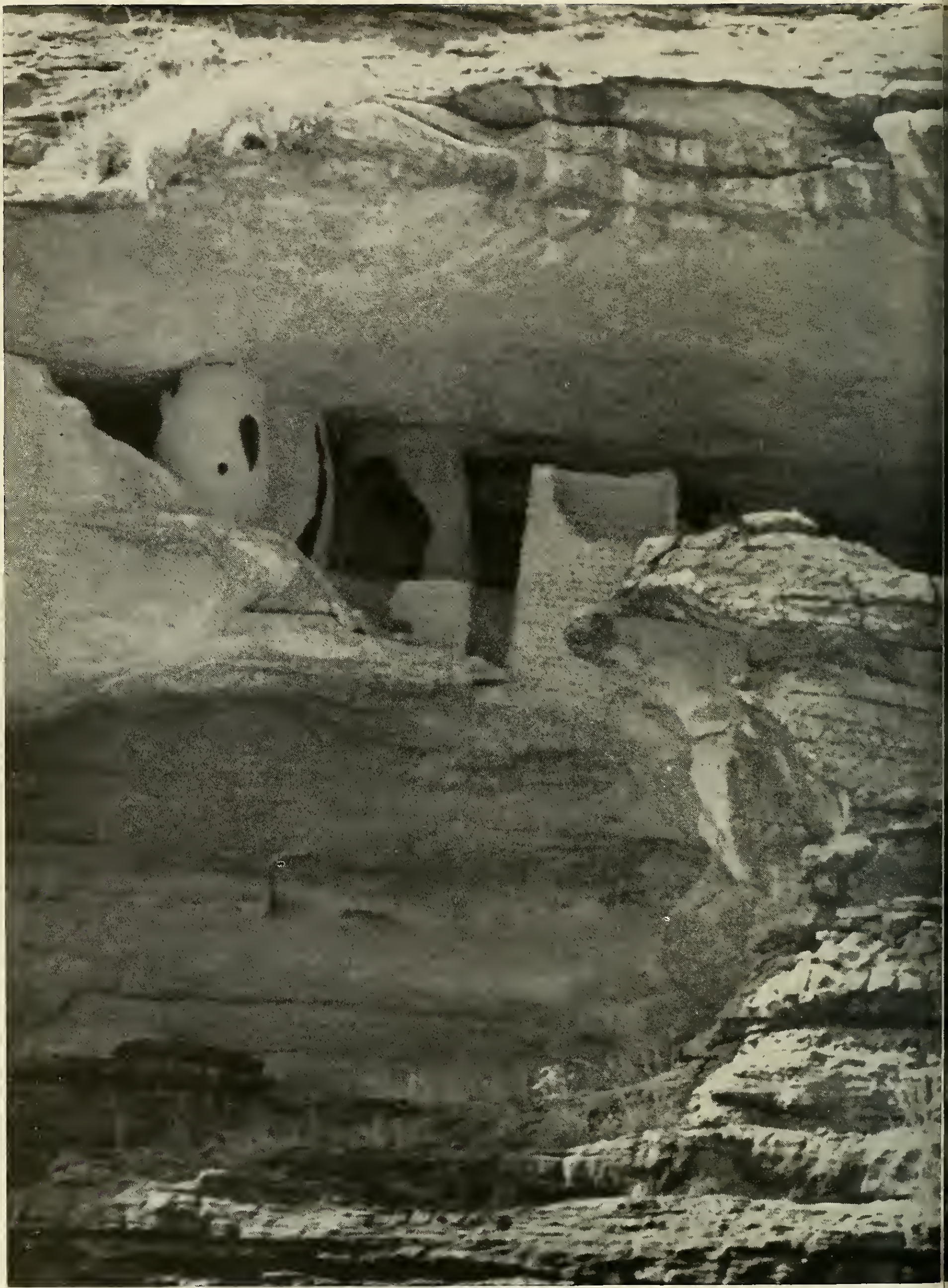
task is hereditary, smooth out the sand beneath the tree. Then they place sticks, stones, and peanuts in various ways within marked squares, each arrangement of objects representing a question that has been posed by a townsman. During the night, the ghost fox comes to eat the peanuts, thus leaving tracks and disturbing the arrangement of the sticks and "writing." At dawn, the old men return to read in the sand the messages that answer the villagers' questions (see photograph, page 26). The fox writers live on food and money offered in payment for the answers thus obtained.



CHILDREN SWARM, single file, *above*, up the narrow pass to Sanga villages.

SPRING is the water source, *below*, for Dogons inhabiting Sanga community.



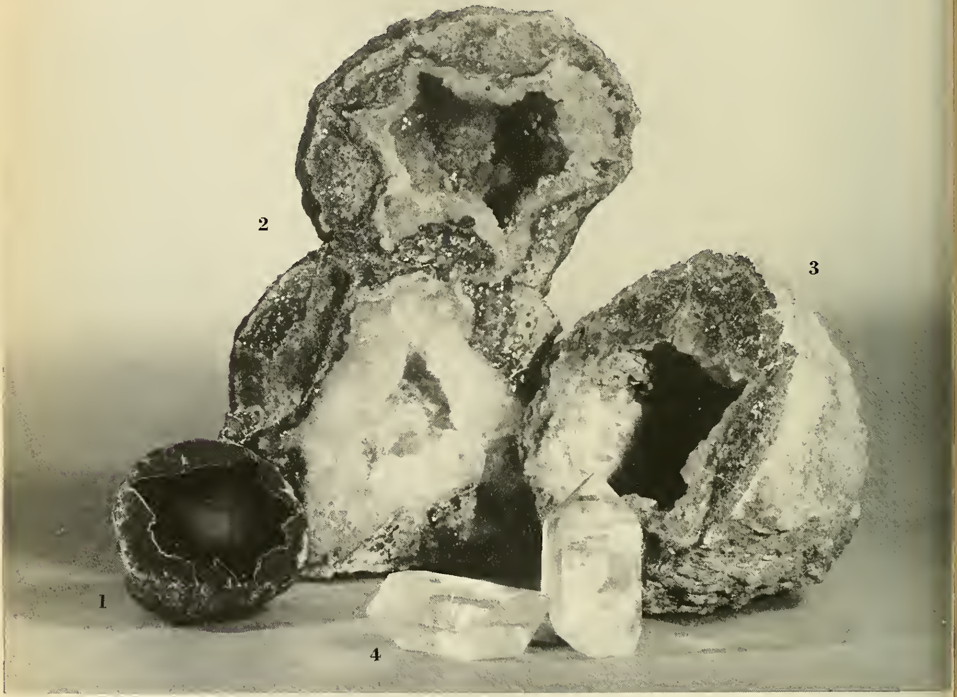


“Caves of the Ancestors” in the Bandiagara Escarpment have interior structures of mud, which were formerly used as granaries, but which are now ossuaries containing bone of an estimated thousand tribesmen. They were slaughtere

Dogons say, during a night raid by an entire tribe of Fula warriors, former Séno Plain enemies of the Dogons. Fula infiltrated the Sanga community with help of a treacherous sentry guarding the steep defile leading to Dogons' villages.

TREASURES FROM THE EARTH
FOR THE COLLECTOR AND DECORATOR

Thunder eggs are partially or completely filled openings in rhyolite nodules. These polished halves are handsome pieces showing the perfection of nature's handiwork. The name is derived from old Indian legends. The Indians believed they were formed by their gods hurling thunderbolts from the sky. The small solid thunder eggs are from Oregon. The larger ones have quartz lined cavities and are from Mexico.



1 – Oregon Thunder Egg about 3″ wide $2.50 each postpaid . . . 2 – Double Mexican Thunder Egg about 7″ wide $16.50 each postpaid . . . 3 – Mexican Thunder Egg about 5″ wide $11.50 each postpaid . . . 4 – Terminated Quartz Crystals from Hot Springs, Arkansas, ranging in size from 2 to 3 inches. Each crystal $1.50 postpaid . . . The above specimens are available in limited quantities.

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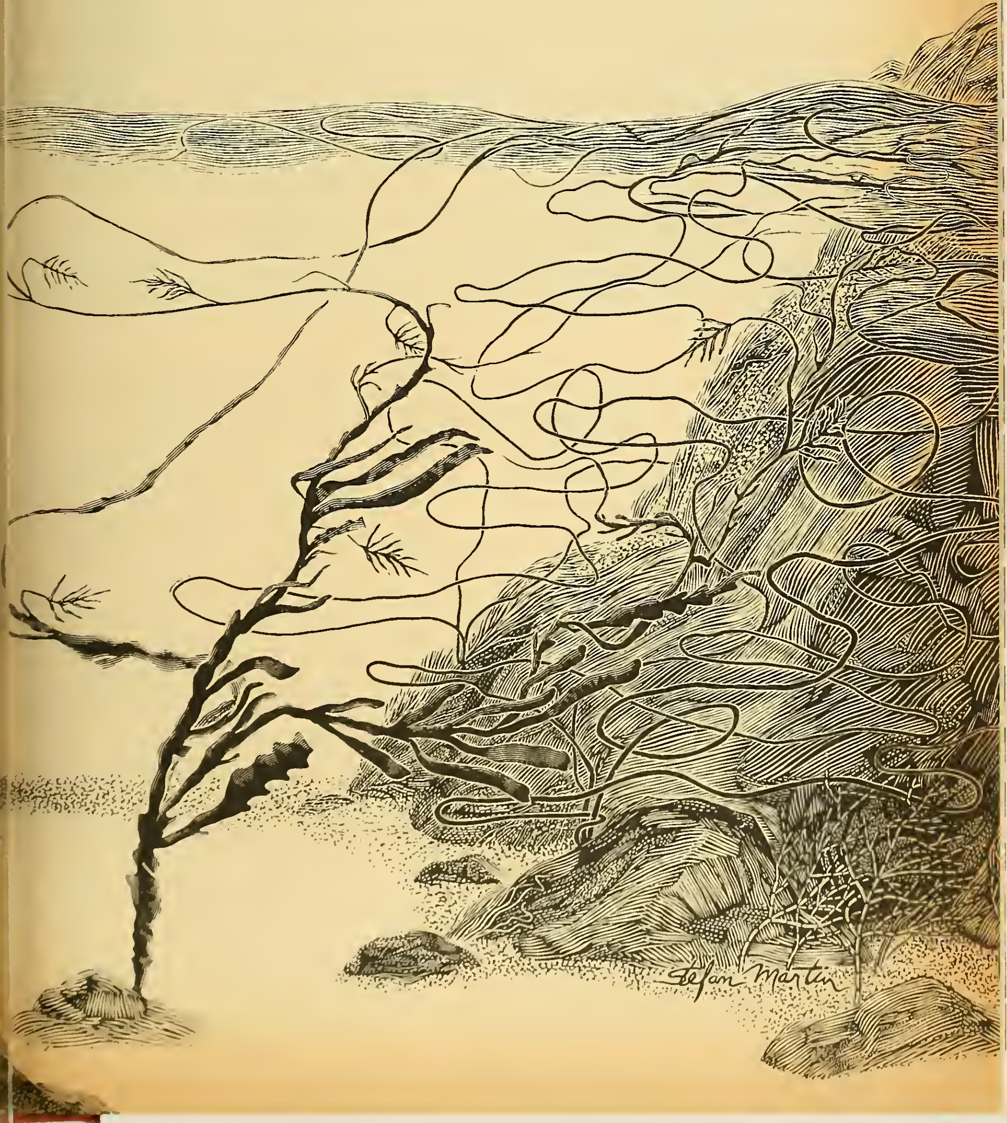

Stefan Martin

THE MARINE ALGAE

In sea's "weeds" may lie the future's insurance against starvatio

By E. Laurence Palmer

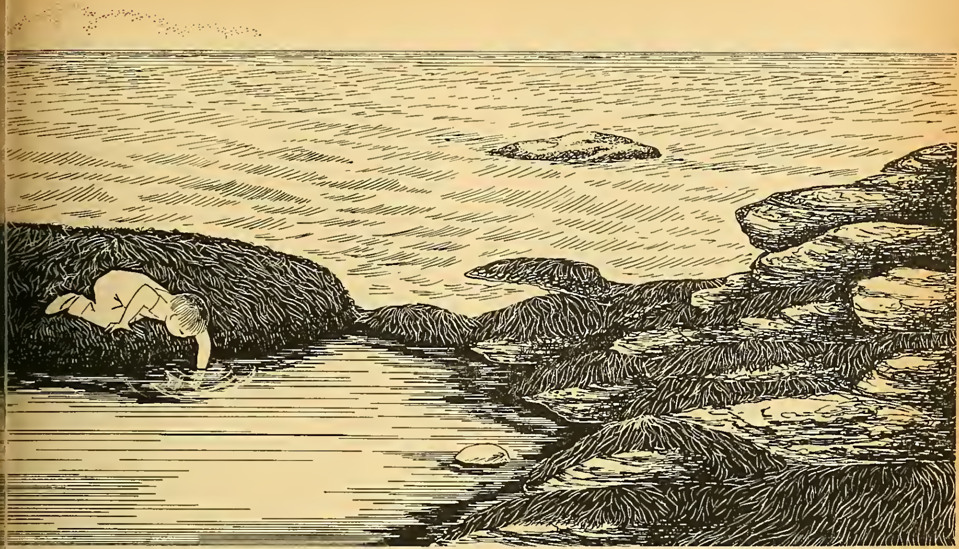
Quintus Horatius Flaccus, more familiarly known to us as Horace, once wrote that: "Noble descent and worth, unless united with wealth, are esteemed no more than seaweed." While the time span back to the day of Horace — who was sixty-five years old at the beginning of the Christian Era—is of course relatively short, geologically or biologically speaking, and the facts and principles on which science is based have not changed, our knowledge of the marine algae has been enormously expanded. Today, we see in the marine algae — Horace's "seaweed"— a potential for great wealth and a great opportunity for new discovery.

Few references to the seaweeds appear in either Testament of the Bible. The usually all-observant Shakespeare seems to have given them but little attention. Even Hemingway, considered by some as the spokesman for our time, writes more about the great fishes than of the plants that form the basis of their food supply.

It is probable that life found early expression on earth in the seaweeds, and it is possible that these same "weeds" may offer us a major hope for survival in some future time. They may perhaps guarantee the human race a future that will not be characterized by nea starvation conditions. The sea and its weeds, havin generously nurtured us in the past, may well be utilize to save us in the future.

The thirty-eighth unit in this series of education inserts was published in February, 1946; like this uni it dealt with various species of marine algae. There no duplication of the species considered in the tw units, however. Among the thirty-two species dealt wi then, no extensive notice was given the highly significa plankton organisms, some of which should be thoug of as marine algae. Nor did we consider the relative few—but sometimes significant—flowering plants th are to be found in the sea and associated with mari algae in brackish waters. The plants we consider here a those that live in salt or brackish water, and that are, have been, attached to bottoms where the water is n deep enough to cut off light needed for plant growt

For the most part, the world of marine algae is limit to coast lines. However, coast line plants are ofte torn free from their original attachments to the bottor and continue to grow and develop while they drift



Marine algae may be studied on kelp-covered rocks at tide line.

the ocean. Under these circumstances, it is possible to find marine algae anywhere near the surface of the sea, from the Arctic to tropical regions; and on rocks, sand, or in the ocean depths.

Among the factors that determine the kinds of seaweeds to be found in a particular place are sunlight, temperature, the chemical and physical nature of the sea bottom, violence of wave action, pollution, abundance of animals that feed on the plants, and a number of other factors. Only about two per cent of that part of the surface of the earth covered by the seas possesses water shallow enough to permit the entrance of light sufficient to support plants; and much of this area has a bottom of loose, shifting sand or mud, or is otherwise unsuitable for plant growth.

There is justification for the division of the seaweed-supporting areas of the oceans into a number of subareas. For example, there is the area permanently below the low tide mark, an area that never becomes dry, and is never subjected to the extremes of heat, light, and violence that affect the strip between the lines of lowest and highest tides. This is an area that may be explored with varying degrees of safety, and for varying lengths of time. In the intertidal area, most of the plants and animals are first submerged in sea water for about six hours and then exposed to drying for a similar length of time, twice a day. The existence of life under such conditions presupposes an ability to make some remarkable adjustments, or adaptations. The reproductive, feeding, and protective activities of living organisms must be fitted into the situation, and no two kinds of living things meet these conditions in an identical manner.

It does not take a trained ecologist to recognize the fact that there are several different zones of plants along our shore lines. There is an uppermost beach area, above the highest tide, that is sprayed by spume and reached occasionally by the highest waves. Marine algae that require submersion in salt water need not, of course, be expected here, at least not in abundance. This supralittoral zone is wet by the high spring tides and by storm waves; and from this zone, down through the tidal zone, we may recognize several other areas on such places as exposed rocks, piers, or pilings.

THE highest tide area is ordinarily bare of most marine algae, but it sometimes displays Enteromorpha and Cladophora, described in the chart section that accompanies this insert. Below this, down to the low-water mark, is the realm of the rockweeds, which are more fully described in the thirty-eighth insert. Below the area marked by the highest low tide and lowest high tide, is the region dominated by, or at least characterized by, plants of the order Laminariales. (Refer to numbers 6-11 in the tabular description, and to other plants of the order shown in the thirty-eighth insert.) Also found in this zone are the coral-like algae.

The plants of this general area must be able to survive conditions that would be fatal to most plants. They must withstand the beating of waves that strike them

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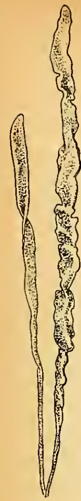
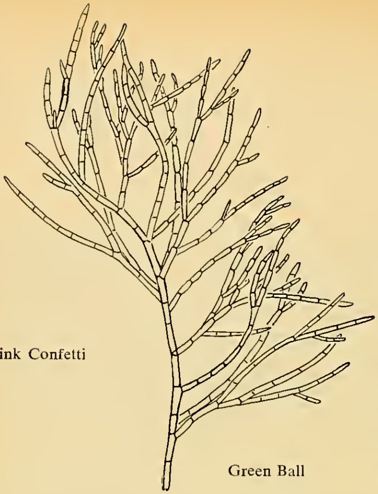
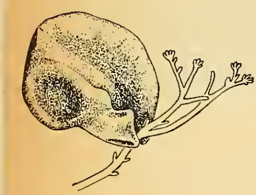
DR. E. LAURENCE PALMER, for many years director of NATURE MAGAZINE'S educational program, continues his special inserts in the pages of the combined magazines.



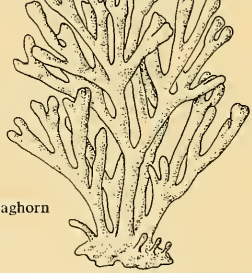
Link Confetti



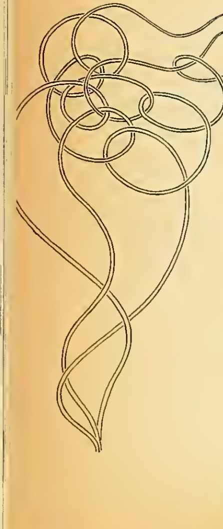
Green Ball



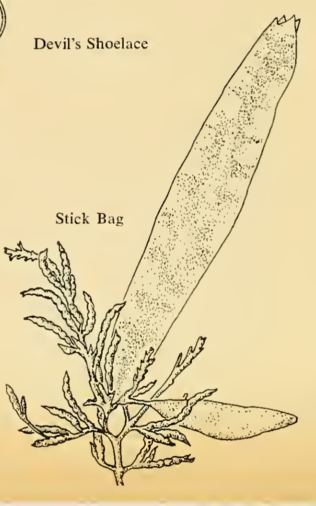
Oyster Thief



Sea Staghorn



Devil's Shoelace



Stick Bag

from all directions. They must survive extremes of hea
light, and desiccation, and they must support the inroa
of the animals and plants that may feed upon thei
Some must survive burial by shifting sands, and t
grinding of loose material on the ocean bottom. Not
few must exist in the pollutants that float on the surfa
of the ocean, and that may become especially conce
trated along the edge of the shore.

Botanists are not wholly in agreement as to the prop
classification of marine algae, and since these studen
of plants do not agree, we cannot criticize inconsistenci
of students who propose other arrangements.

BASICALLY, the marine algae belong to four or fi
groups. The blue-green algae—the Cyanophyce
or Myxophyceae of some authors—may be either fix
or free-floating, and may be found abundantly in fresh
well as in salt water. Some of these were considered
the sixty-ninth insert of this series.

The green algae belonging to the Class Chlorophyce
include link confetti, the "green ball" shown in this inse
sea lettuce as shown in the thirty-eighth insert, and mo
of the algae that are figured and described in the sixt
ninth insert. They are for the most part green in colo
as their class name implies, and may be either free-floa
ing or fixed to the sea bottom or rocks.

The brown algae belonging to the Class Phaeophyce
include the oyster thief, stick bag, devil's shoelace, sea
sucker kelp, sea cabbage, sea palm, pompon, feather bo
and the woody chain bladder algae, all figured in th
insert. Eight of the algae considered in the thirty-eigh
insert also belong to this group. Few of these are foun
in fresh water. They are considered by some as t
most advanced of the thallophytes; they reach the
maximum development in the cooler seas, and possib
dominate the rocky intertidal areas. A giant kelp of t
Pacific, growing off the Chilean coast in waters to abo
250 feet deep, belongs here. At least one of the brow
algae grows on other plants.

In this insert we have specifically considered a numb
of the red algae belonging to the Class Rhodophycea
Nine of the group were considered in the thirty-eigh
insert. Six are in this unit, and one was in the sixty-nin
unit. Most of the members of this group are marine, a
are perhaps the most beautiful of all the larger mari
organisms. The common name may be a misnomer, b
cause we find members of the class that are red, purp
brown, violet, and green, and some that may be iridescen

ON the whole, these plants are found at relative
shallow depths, and while some of them may a
tain a length of more than six feet, most of them a
much smaller than the brown algae. The red algae a
most abundant in temperate seas, and relatively few a
abundant in the intertidal zones. Some have played
prominent part in the building of lime deposits, and m
be closely associated with the corals.

Certain writers recognize a special group of alg
known as the yellow-green algae, prominent among whi
may be the diatoms, considered by some as belongi
to the Class Bacillariophyceae. Some of these are fre
swimming and motile. Some merely float; others may
attached by strings of mucus. They serve as food a
shelter for many aquatic organisms, and may be t

basic food for minute organisms that in turn feed larger creatures. They are found in fresh as well as in salty and brackish waters, and from their shells man makes polishing powders, explosives, toothpaste, filters, and cement strengtheners. Their reproductive capacity is tremendously large, which may, in the long run, affect man.

We have all, at one time or another, calculated the age of a tree by counting the rings of its wood. To a limited extent, we may do something of this sort with certain of the marine algae. Some of these algae are short-lived, many of them being annual; while some may live for a number of years. The pompon shown in the accompanying chart section sheds some of its streamers each year, leaving a series of scars that allow one to recognize the growth of the year.

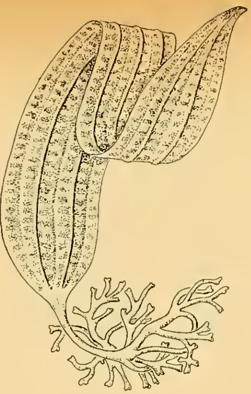
Normally, a submerged habitat may be considered more favorable to the growth of marine algae than an area exposed to the air, to large temperature variations, or to other extremes. Interestingly, the prolific growth of deeply submerged seaweeds reduces the amount of sunlight that can penetrate the water, and therefore a heavy growth may affect a given area botanically.

Some marine algae may grow in length at the rate of ten inches a day, but such a rate is not common to all algae, nor does it remain constant for any given alga. A plant that may grow at the rate of ten inches a day from March to June may grow at the rate of only one inch a day during June and July. Then, too, the growth of plants in deep water may be more rapid than that of plants in the shallows. Competition is often a major factor affecting rate of growth and an early seasonal start may be of importance. Sediments in the water may at times cut down the available light at various depths, and affect the growth of algae there. In addition, seasonal storms and floods may sometimes considerably affect the prosperity of a loosely fixed or free-floating seaweed.

Most of the marine algae possess two or three methods of reproduction—some have more. The simplest mode of reproduction is by fragmentation, in which each of the fragments becomes an independent organism. Then there is reproduction through the development of asexual spores, some of which swim and some of which do not. Sometimes these spores are produced in specialized regions of the plant, and in special structures; but this is not necessarily always the case.

In some algae similar spores may unite, the combined spores forming a new plant. In other algae, spores that differ conspicuously may be formed. A pair of unlike spores may unite in true sexual reproduction, and from such a union there may develop a new, individual plant. When this is the case in the marine algae, it is common for the resulting plant to produce asexual spores, so that there is an alternation of generations between plants that produce sexual spores and those that produce asexual spores. This alternation of generations in the marine algae is infinitely varied—to the delight as well as the occasional consternation of the botanist. Seasonal influences may affect the nature of such generations rather profoundly, but over the course of time a species continues to exist in spite of its several variations.

The origin of the marine algae is lost in geological antiquity. We can reasonably assume that, where the normal products of algal activity are found, algae must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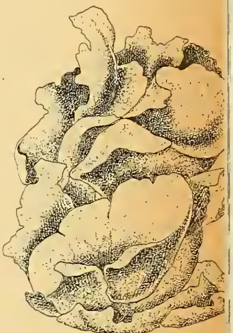
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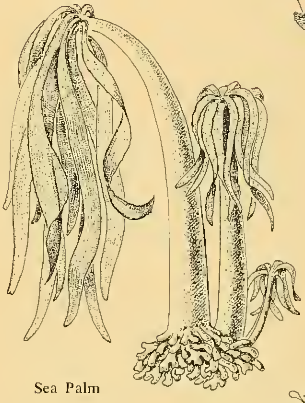
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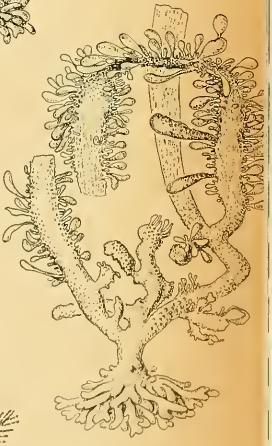
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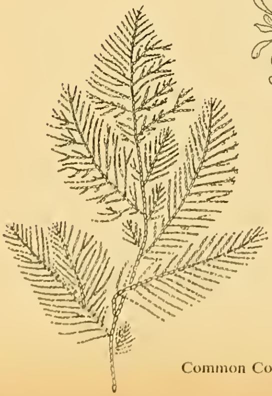
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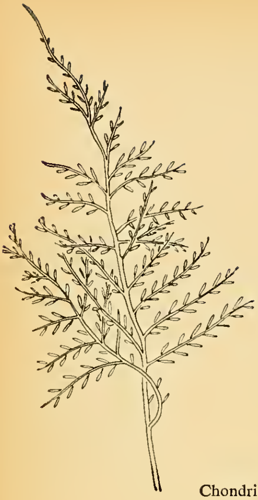
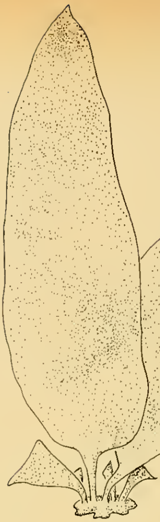
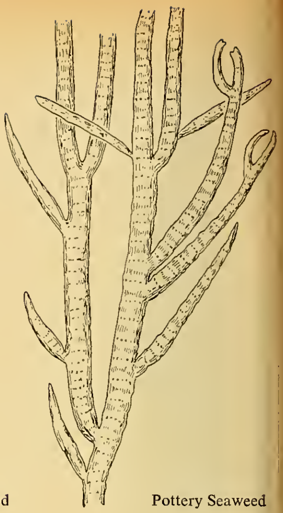

Chondria


Iridescent Seaweed


Pottery Seaweed

have existed to produce them. (There are, however, coral and lime deposits and diatomaceous oozes in geological deposits that do not yield samples of the organisms that must have been their creators.) The earth's oldest fossil remains may well be associated with marine algae; and it is safe to say that the marine algae will be among the last representatives of life on earth.

Botanists who pry deeply into the behavior of marine algae—and fresh-water algae as well—recognize that their growth may be affected by various physical factors. This is also true of their reproductive processes. There have been some most ingenious studies based on the exposure of marine algae to light, pressure, movement, electricity, various chemicals, and to combinations of these factors. As a result, some of our laboratory manuals can now specify the proper agent for desired experimental results in dealing with the algae. Also, biological supply houses are now often able to submit materials that make it possible for a student living inland to learn as much about the algae as those whose homes are on or near one of the seaboards.

A kelp-covered rock at the tide line is almost always worthy of study. When the tide is out and the sun is high, environmental factors are most hostile for the marine algae. Water supply is limited. Temperatures are excessive. Light may be intense. Kelp-eating animals roam the shores, feeding on the plants. Portions of the plant may wither and die, or become severely fractured. Fortunately, however, the volume of the kelp blanket is such that, while exposed parts of a plant may suffer, there is much plant material that is protected through being covered by a soaking blanket of the kelp itself.

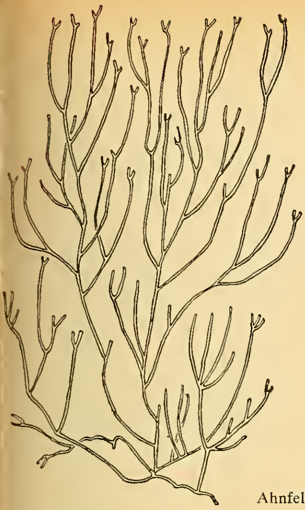
Plants near the low-tide mark may be subject to severe treatment for only a few minutes, until the tide turns; and even those higher up may be washed now and then by the dashing of the waves. It is interesting to note that the intertidal strip is more heavily populated with se plants that may survive *emergence* than it is with lan plants that can survive *submergence*. An evaluation o the comparative hardiness of land and marine plant can be made, based on the evidence of an intertidal stri and might well prove most rewarding.

The destruction of marine plants by desiccation, predation, and by violence and crowding is obvious an important; but what really counts is whether such destruction is greater than the constructive work done b the organisms over the same period of time. The fact tha there is a great surplus of observable material shows tha the constructive forces constantly win. If such an observation is extended over the course of a year, it will b evident that there are periods when "hard times" are th order of the day; but in the long run these are balance by the periods of prosperity.

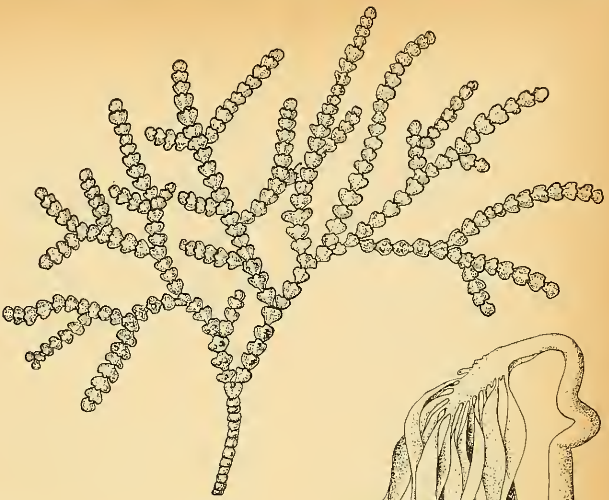
It may be well to think of this conflict not only i terms of what happens to a given plant, but of wha happens to the biological material collectively. Th crowding of healthy material may not only save portion of a plant, but it may also protect smaller or more immature individuals of the same kind of plant, or perhap less hardy plants of other species.

There are pessimists who say that human starvatio is inevitable in the distant future. Optimists, however, point with considerable confidence to the grea potential of the marine algae. Such plants may be foo for man, for domesticated beasts, and for animals of th wild. They have an important place in man's vision of th future. Even today the marine algae form the basic die of many human beings, and seaweed often enters unobtrusively into our diets here in America. The role of some marine algae as food for human beings are mentioned in the chart section of this insert.

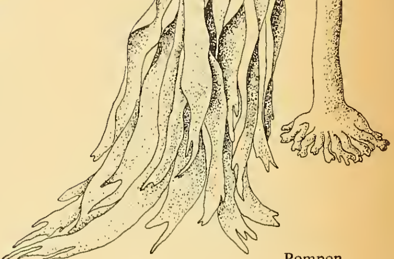
Health, of course, is a topic important to all of us, an



Ahnfelt's Seaweed



Leaf Coral



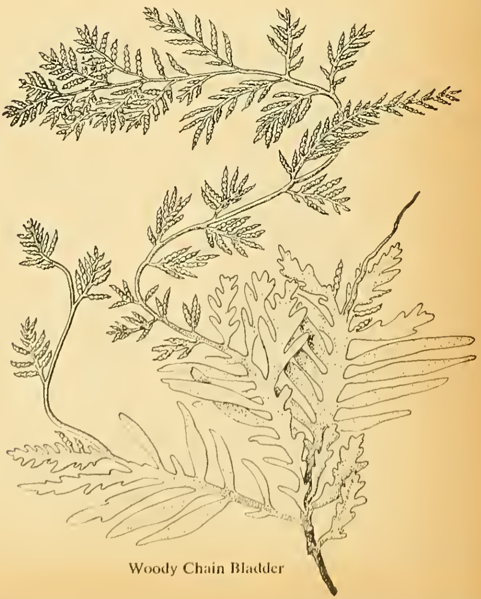
Pompon

most studies of disease involve the study of microscopic disease organisms. We can all identify a flock of geese without studying the details of its individuals; and so it s that microbiologists have learned how to recognize a colony of microorganisms without troubling to observe its individuals. This sort of study frequently involves the culture of the organisms on some medium that possesses a variety of special qualities. Agar is such a medium in common use, and agar is basically a marine alga. Its production is essential to our present-day civilization. Within the past few years, the Russians have announced that they are producing a superior agar from marine algae not previously used for the purpose. They have not yet claimed to have created algae, but they have unquestionably found new uses for the plants that for hundreds of years were "esteemed no more than seaweed."

MUCH of the gelatin used in cookery may originate in the marine algae, and many of the foods used by hikers and explorers make use of marine algal material, which is easy to dry and yet which, with the addition of water, is quickly restored to the desired volume.

It is pleasant to assume that the supply of marine algae is inexhaustible. Americans have made that same assumption in the case of their forests, their topsoils, their buffalo herds, and their passenger pigeons. Methods we are now developing for harvesting marine fishes presupposes an inexhaustible supply of marine algae on which such fishes are dependent, so we shall probably have to earn our conservation lessons once again.

Today there is much concern over the needless destruction of marine life, and it is most encouraging that our colleges and universities are recognizing the importance of marine problems. Even those institutions located far from the ocean shores are providing specialized training that may make our future dealings with the sea much more intelligent than they have been in the past.



Woody Chain Bladder

	DESCRIPTION	RANGE AND HABITAT
Link Confetti *Enteromorpha intestinalis* *Chlorophyceae, Ulotrichales, Ulvaceae*	Slender, flattened ribbons to one cell thick, to more than one yard long, tubular, bright green, to 1½ inches wide, usually gas-filled, and with constrictions that give plant intestinal appearance. This species is unbranched, and threads are usually less than 1⁄16-inch wide. Highly variable.	Almost world-wide distribution, with most species restricted to salt water. Habitat ranges from polluted through brackish to pure sea water, with specimens on ship bottoms able to survive fresh water temporarily. Attached by basal area to bottom between 3-foot and mean low tide marks.
Green Ball *Cladophora trichotoma* *Chlorophyceae, Cladophorales, Cladophoraceae*	A bright green ball about the size of a small lemon, which, if detached, may spread into a thin, green tissue to 3 inches or more across. The jelly balls include branched or unbranched threads of barrel-shaped cells, attached end to end.	More than a dozen Pacific coast species, and many on the Atlantic Coast. May or may not be conspicuous in tidal pools, with "ball" effect most common where wave action on sand is present. The plant may hold sand particles at branches when it is growing on rocks away from free sand.
Sea Staghorn *Codium fragile* *Chlorophyceae, Siphonales, Codiaceae*	Erect, spongy, forked, cylindrical, with branches equal but not straight. Plants arise from branched filaments that are without cross-walls. Commonest species have erect branches, commonly inflated, while others do not. Shoots are to 10 inches long and to ¼-inch wide.	Commonest Atlantic species may be *dichotoma*, while commonest Pacific species may be *fragile*. This species may be greenish black or coated with whitish hairs. Inflated branches with length about 10 times the diameter, or more. Most abundant in warmer seas.
Oyster Thief *Colpomenia sinuosa* *Phyophyceae, Punctariales, Encoeliaceae*	Like an olive-brown, inflated balloon to 2 inches through when young, appearing as a floating globular sac filled with water or air. With age, however, these bubbles burst, and the deflated unit may bear wrinkles resembling the surface of the brain. Surface may bear tufts of hairs. Crisp, not slippery.	On Pacific coast, found from Alaska to southern California, from the shallows to 40 or more feet in depth. May be found in Florida as well as along the length of our western coast, but with some seasonal variation obvious. Believed introduced to U. S. from Europe; is world-wide in warm areas.
Stick Bag *Coilodesme californica* *Phaeophyceae, Punctariales, Encoeliaceae*	Appears like a bag attached to an alga. May be to 1 yard long and to 4 inches through, but is normally much smaller; is attached by special structures through a solid base, and is commonly olive-tan to brown in color. It is commonly borne at right angles to the supporting host alga.	Commonly grows as attachment to woody chain bladder alga (which see) from Alaska to southern California, and from near surface to a depth of more than 30 feet. Not commonly abundant or conspicuous, and may seem absent in particular seasons. May seem bladelike at times.
Devil's Shoelace *Chorda filum* *Phaeophyceae, Laminariales, Laminariaceae*	Slender, ropelike fronds less than 1 inch in diameter, frequently to 12 feet long and reportedly to 40 feet long. Colorless hairs of a delicate nature cover young plants, but old ones commonly have decayed tips. Whole mass looks like an aggregation of snakes. Brown, with a central air cavity.	This species is well represented on each side of the North Atlantic, is common near low tide level from New Jersey north, and is usually attached to inorganic material. The related *C. tomentosum* ranges north of Cape Cod. *C. filum* ranges from New Jersey to Baffin Bay.
Seersucker Kelp *Costaria costata* *Phaeophyceae, Laminariales, Laminariaceae*	Length of flat blade may be to 10 feet and width to 1 foot, arising from a tough, branched holdfast, and displaying up to 5 prominent longitudinal ribs, with 3 showing on one side and 2 on the other side of the blade. Area between the ribs is shirred or puckered, giving the name "seersucker."	Four species and one variety of *Costaria* are now recognized along coasts of Pacific Ocean in Japan and North America, ranging from Bering Sea to southern California, and found in deeper waters in southern part of range. Some authorities consider that there is but one variable species.
Sea Cabbage *Hedophyllum sessile* *Phaeophyceae, Laminariales, Laminariaceae*	Compact mass of fronds, densely crowded into something that resembles a cabbage head with individual "leaves" almost circular, and from 15 to 18 inches across. Mature plants are fastened to rocks by holdfasts, or fibers that develop from blades' bases. Blades are either smooth or wrinkled.	Two species of the genus cover our Pacific coast from central California to Bering Sea, on rocks near low-water mark where wave action may be most violent. *H. sessile* may be found south to central California. Its blades are dark brownish green, with a heavy leather-like texture.
Sea Palm *Postelsia palmaeformis* *Phaeophyceae, Laminariales, Lessoniaceae*	May be found in "groves" where the surf is the most severe, with submerged individuals superficially resembling palm trees, usually with many arising from a common base. "Stem" up to 2 feet tall, with upper portion flattened, and with a hundred or more 12 x 2-inch streamers.	From Vancouver Island, in British Columbia, south to central San Luis Obispo County in California. Blades have sharply toothed margins and deep longitudinal grooves alternating on the two sides. Some may be found in partially submerged rocky ledges somewhat offshore.

REPRODUCTION	ECOLOGY	ECONOMY
Basal or other tissue may break to form new individual plants vegetatively, or cells may yield 4-8-16 zoospores, each with 4 mobile swimmers; or may yield sexual cells, each with 2 swimmers, which may have sexual union. May develop without union parthenogenetically, or be a resting stage.	Plants may be solitary or grow in crowded clusters attached at base, or sometimes free-floating. Most commonly observed in tidal pools or just below low tide mark in protected areas, and observable at almost any time of year as a green mat of threads, usually attached to the bottom.	Useful as a basic food for fishes and other marine animals, and may serve as a purifier—or contaminant—of water. Deflated threads may have released green cell contents into water, leaving the threads colorless. Species recognition requires ability of the specialist in many cases.
Vegetative tissue may divide to produce new individuals, or cells may yield identical, oval, 4-swimmered cells freed from terminal branches through upper pore; or may yield 2-swimmered gametes, which may unite sexually or germinate without union parthenogenetically.	Green ball is perennial and may hold ball shape in aquarium for more than eight years. Expanded cushion forms may occur in deeper water where there is but little water motion. Some species of *Cladophora* are limited to fresh water, while others are marine or cosmopolitan in many respects.	Basically identified with pollution and purification of water and with service as a basic food for fishes—or of the animals on which fishes feed. May serve in some capacity as silt or sand anchor, assisting in stabilizing loose material on the bottom of waterways —fresh, salt, or brackish.
Plant may divide to reproduce vegetatively. Asexual spores are not produced. Cells yielding sex elements are borne laterally, with the male yellowish green and the female blackish green. United gametes form a zygote that develops into a new plant body.	Interior of branches is normally filled with densely crowded masses of hairs, and the hairy exterior is commonly covered with mucilage. The shoots may appear greenish black or white-fleeced, and may persist through the winter—or even sometimes for several years, usually in areas of mild climate.	Closely related forms may be important in the development of algal reefs. The Hawaiian food *limu* may include *Codium*, with some forms eaten raw and some cooked with a variable palatability and variable periods of deterioration. May be cooked with combinations of fish, shrimp, meat.
Unicellular spore cases are unknown but many-celled reproductive organs are found around hair tufts; those opening in autumn free units that act as zoospores, those in spring behaving like sexual units. Not always agreed whether main tissue represents a gametophyte or a sporophyte stage.	Sac develops because of continued crosswise division of outer layer of cells. Sac remains attached by special disc that holds it to an object like another seaweed—or even a young oyster—with which it comes into contact, usually when plant touches bottom at low tide levels.	When an oyster becomes attached to oyster thief, it may be lifted from bottom and floated out to sea and lost. In Europe, nets and ropes are drawn over oyster beds to free oysters from seaweed. Balloon fills with gas at low tide, floats oysters out at high tide, often in great numbers.
Spore cases are only one-celled, usually separated from each other, pear-shaped, and imbedded just below tissue surface. Gametophytes are microscopic threads several cells high, which produce gametes that resemble each other but which unite sexually to produce basis for the sporophyte.	An annual plant that appears during May, and which may disappear by August. It may be abundant where host is present on which it may grow but apparently utilizes host only for support and is not a definitely destructive parasite to be kept under control.	Not of great, if any, economic importance; but is of intriguing interest, both because of its association with its host and its specific nature. It is also of interest because of its seasonal appearance and its unique—but not obviously functional—saclike form.
Asexual spores borne by somewhat cone-shaped structures on the surface of the blade. From these zoospores, produced in late summer and autumn, arise the common, conspicuous annual plants. Sexual reproduction takes place through microscopic structures.	While many marine algae favor the warmer waters, this species does well where it is cooler; sometimes dense growths of this species rival in beauty the better-publicized tropical forms. The North Sea and the English Channel are reported to have beds to 20 miles long and to 600 feet wide.	Chorda with diameter of a lead pencil and a length of up to 20 feet has common name of "mermaid's fishing line." Most members of this family have a broad, flat blade, much unlike the ropelike character here noted. Young plants adhere to mounting paper because of their mucilaginous nature.
From midsummer to late autumn, mature blades may be covered between the ribs with spore cases. The plants are perennial, at least as far as the portion below the blade is concerned. Gametophytes are filamentous, microscopic, bear male or female organs.	These dark-brown plants may grow rapidly, a blade increasing as much as 1 inch by day and ½ inch by night, with growth mostly at the widest part of the blade near the base. In 9 weeks, the hull of a sunken ship had become completely covered with this particular kelp.	Massed growth of plants provides needed shelter for many small marine animals that serve as a basic food for fishes. There does not seem to be an important specific economic use for this species, but it plays a part in the general roles filled by its relatives.
In this family, reproductive areas are on the blade, and are never on special structures bearing special spores. In this species, the sori are found at the base on each side of the blade. From these are freed the spores, which in turn develop the gametophytic stage that bears the true sex organs.	Found in crowded masses on rocks heavily beaten by the waves, they provide welcome food and shelter for weaker plants and for the small animals that play a part in the economy of the site. The presence of mucilage ducts on the blades may contribute to survival under existing conditions.	Wave violence and alternating exposure to sun and dryness, and submersion in sea water limit the kinds of plants and animals that can live where the sea cabbage prospers, but its tough holdfasts and overlapping "leaves" provide the necessary conditions for the growth of other marine plants.
Reproductive spore cases are borne in the longitudinal grooves of blades beginning to yield spores in late spring, and continuing until the blades are shed or eroded by late summer or autumn. Only one-celled spore cases are found, and gametophytes are as in relatives.	The glossy olive-brown stipe that supports the fronds is elastic, and it may be bent flat only to recover when pressure is released. It is doubtful if any other plant can more genuinely express the conflict and turmoil that exists in a wave-beaten, rocky shore of caves and crevices.	Probably of little or no economic importance, but a uniquely typical plant for the wave-beaten rocky exposures of its habitat. Undoubtedly provides some food and shelter for animals that share the same territory, and appeals to artists depicting its habitat.

	DESCRIPTION	RANGE AND HABITAT
Pompon *Pterygophoro californica* *Phaeophyceae, Laminariales, Alariaceae*	Like a stiff, erect stick to more than 8 feet long, ending in a terminal blade to 4 inches broad and to a yard long, with to 40 accessory streamers attached near base of terminal blade. Both terminal and accessory blades are smooth and without midribs, at least in their laterals.	Found from British Columbia to northern Baja California, particularly in deep crevices under water where waves are violent. Distribution is apparently limited to shore area well below low tide level, and is considered a deep-water resident.
Feather Boa *Egregia menziesii* *Phaeophyceae, Laminariales, Alariaceae*	A short, 2- to 3-inch stalk is supported by rugged, branching holdfasts to the ocean bottom, and bears up to 25 irregular branches that in turn may branch to form a maze of material. Each of the major branches bears many blades of varying sizes and shapes, some being bladders that float.	From British Columbia to Point Conception in central California between 2-foot and mean low tide levels on rocky beaches or shores, with plan reaching a length of more than 20 feet. Plants are deep chocolate-brown, and are largely covered with tubercles. The sporophytes are perennial.
Woody Chain Bladder *Cystoseira osmundacea* *Phaeophyceae, Fucales, Sargassaceae*	Length to more than 30 feet, and blackish brown in the lower areas to light tan in the upper portions. A basic central stalk to more than 1 inch thick yields several branches many feet long, flattened at bases and cylindrical at tips, with a chain of tiny bladder sacs borne on the ultimate units.	Ranges from the State of Washington south along the coast to Lower California in the Ensenada region, and is found between the mean low tide levels and the 1½-foot tide levels. Species belongs to family of which sargassum is member, and which is basis of Sargasso Sea plants.
Common Coralline *Corallina officinalis* *Rhodophyceae, Cryptonemiales, Corallinaceae*	Like slender, jointed, bushy limp, fragile coral that reaches a height of to 3 inches. The joints are cylindrical, wedge-shaped, and flattened above. Varies from reddish purple to gray-green, but if exposed to the sun may bleach to a pure white. Branches spring from joints directly below.	A native plant of California shores, and found along our Atlantic coast north of New York. Several genera are all characterized by the stony encrustation of the fronds. Some of these are pink, and some brown. This species is found from the intertidal area and the tide pools out to rather deep water.
Leaf Coral *Bossea orbigniana* *Rhodophyceae, Cryptonemiales, Corallinaceae*	Height to 6 inches. With densely crowded branches looking like jointed leaves, or with flattened, branching, jointed stems. Branchlets are flat, to $\frac{1}{16}$-inch long, and wider than they are long. Uncalcified joints permit necessary flexibility. A midrib is rather obvious but not conspicuously so.	Ranges from Oregon to southern California, and is found in South America with an abundance of species in many places. This species is found growing on shells and rocks, from between the mean low tide level to the minus 1½-foot level. It is related, of course, to the coralline just discussed.
Ahnfelt's Seaweed *Ahnfeltia plicata* *Rhodophyceae, Gigartinales, Phyllophoraceae*	Appears like a black, crooked, stiff, wide, forking wire, the stems being about the thickness of a coarse knitting needle. The whole plant makes a rather dense, bushy tangle of branches, and is a far cry from the average marine alga. The branches are cylindrical in their cross section.	This species ranges on Pacific coast from Alaska to Carmel Bay in California, and on Atlantic coast from New York to the north. It was originally described from England. The deep purplish to black color strengthens the impression that the plant is not organic but rather of a metallic nature.
Iridescent Seaweed *Iridophycus coriaceum* *Rhodophyceae, Gigartinales, Gigartinaceae*	From a short, cylindrical stem develops a broad, wrinkled sheet from 3 inches to 6 feet long, usually with but one blade, but in some related species with more. Submerged in water, may give off brilliant, iridescent, metallic bright blue, green and purple colors.	Ranges from northern Washington to central California, with a half-dozen species on continental United States' Pacific coast. Grows on rocks exposed to strong surf at 1- to −1-foot tide levels. Some species are found locally in great abundance.
Pottery Seaweed *Ceramium rubrum* *Rhodophyceae, Ceramiales, Ceramiaceae*	Fronds like large, leafless branches, with units ending in a clawlike hook. Repeatedly two-forked. Surface covered by a "bark" of small cells, which forms rings at the joints. Conspicuously lime-encrusted, whole plant arises from a basal disc. Usually deep red, with some variation.	Found growing on rocks near shore, on plants, on wood, on shells, or almost any support; from tidal to moderately deep waters in almost all seas of the world. Found throughout the year. Found in the Tropics, and ranges from Florida to Newfoundland.
Chondria *Chondria tenuissima* *Rhodophyceae, Ceramiales, Rhodomelaceae*	Highly variable, bushy plants, to 10 inches high, profusely branched and with growing tips often with clusters of long, slender, branched hairs that do not persist. Like bushy, purple- to straw-colored fine brush, with shoots, arising from a common base, that branch and subbranch repeatedly.	Genus is represented on both Atlantic and Pacific coasts of North America, with this species growing on shells and rocks just below the low tide line and usually in sheltered areas. It ranges from the Tropics to Massachusetts on Atlantic coast, and has two most abundant species in southern California.

REPRODUCTION	ECOLOGY	ECONOMY
Lateral blades bear spore cases that begin fruiting in October and continue until the blades are all shed by winter. From these spores develop the gametophytes typical of the family, and from the gametophytes develop the conspicuous plants considered here.	This is a perennial, at least as far as the central stem is concerned; but the terminal blades are shed and leave scars that may be used to determine the age of the plant. In winter, everything is shed except the supporting stalk. Some Northwest plants live to the age of 13 years at least.	The common name pompon refers of course to resemblance to a stick bearing an aggregation of streamers at its end. Plants provide a degree of food and anchorage for the niche they occupy in the ecology of the seashore, but have obvious economic use.
Some of the lateral sporophylls may be completely covered with spore cases, but the spore-bearing and the sterile branches are not always easily distinguished without skill and opportunity for study. Gametophytic stages are typical and inconspicuous.	In part, because of the great volume of this plant, and because so much of it can be harvested with convenience, the plant is used commonly as a fertilizer. Fertilizing value is like that of barnyard manure, contains more potassium, about the same amount of nitrogen and less phosphoric acid.	The plant provides food and shelter for some marine animals that share its habitat, and it has an intriguing variation in its body structure. It differs pleasantly from the monotony that is common to so many plants—and other organisms, for that matter.
Sexual or basic reproductive areas are borne on the tip branches, the male elements being liberated to fertilize the female. After fertilization and fruition, the air bladders and smaller branches disintegrate. The main stem of mature plant may be scarred, indicating vegetative reproduction.	In the Atlantic area, this group is well represented by the genus *Fucus,* so commonly considered in courses in botany, and also by the gulfweed *Sargassum.* Both of these plants were considered in detail in the thirty-eighth insert on Marine Algae.	Because of the volume of material produced by this alga, its potential usefulness, and its relatively wide distribution, studies toward finding new uses may be rewarding. Possible uses as food, as fertilizer, as medicine, should be investigated.
Reproductive organs are hidden beneath the stony crust on the plant, but may be uncalcified in actual reproductive cells. There is a most involved system of structures and behavior patterns involved in the reproductive story, and even the identification of material is matter for argument.	Plants are not mucilage-covered, as are so many marine algae. They are found throughout the year, and are so variable that they have tempted many students into proposing a variety of names for new species. Names do not usually survive critical studies.	Probably of little direct economic importance, in part because of small size; but over the ages these plants and their relatives have contributed profoundly to the development of reefs in conjunction with the activities of various coral animals.
Uncalcified spots on the segments bear or lead to the reproductive structures, and these are not commonly found on the terminal segments of the plant. In this genus, little is apparently known about the development of the male and female reproductive organs but such a development must take place.	In plants of this type, lime is deposited to a greater extent where there is a good exposure to light, and the amount of lime in the plants in summer is less than it is in winter. Lime deposit is probably associated with removal of carbon dioxide by action of photosynthesis.	These plants are interesting to biologists, but do not yet lend themselves to any man-managed activities that are financially rewarding. However, this is not a reason for assuming that they may not sometime yield some product of major importance.
Spore-producing structures in spots at the surface of the plant, although much of the typical reproductive story of plants of the group is not known. Some of the reproductive structures were once considered to be parasitic plants. The fruiting bodies look superficially like warts.	Branches may be forked up to ten times, with one or two forks believed to form in a year. Plants grow from a horizontal, branched, cylindrical structure. Sakhalin Island, north of Japan, produces *Ahnfeltia* in large quantities.	In 1930, Russians began producing Russian agar from *Ahnfeltia,* which they claim equals, and in some respects exceeds, the usefulness of the best grade agar produced from other sources. This may turn out to be a valuable use of this and related algae.
Male elements produced in extensive areas on face of blade, and the fruiting body deeply imbedded in blade and surrounded by nutritive tissue. From this, issue the spores that start a new individual plant, often far removed from the parent plant.	Aside from the remarkable beauty of the iridescent blades of this alga, the plant is often harvested in great amounts, with one man able to harvest up to 400 pounds at a single low tide. The blade of this species is leather-like unless dried, and then is horny in texture.	From this species is procured a colloid known as iridophycin, which is useful in keeping chocolate in suspension when mixed with milk. Other species are also harvested commercially, giving the plant a considerable economic importance aside from its other values.
Asexual spores are produced from 1 to 3 rows of cells around the joints, or scattered and usually indicated by slight swellings. The male elements are produced from crowded tufts on surfaces of younger parts of plant. The female elements are produced on lateral branches, which are protected.	Fruiting in this species takes place in summer. Masses of this alga may be held together by hooks that react to contact with plants of this or of closely related species. Then rhizoids are developed, which act to intensify the mutual attachment.	Encrustation with lime may make this species an agent in building up lime and coral deposits; ordinarily, this species is not of great recognized economic importance. This is one of the larger species of the genus. *C. pacificum* is West coast counterpart of *C. rubrum.*
Male elements are borne in clusters at branch tips, and the fruiting bodies are borne as swellings back from the branchlet tips, but in the finer branches—not on the coarser portions. The sexual reproduction story is involved, and is described in detail in literature on the subject.	Possibly of major interest only as a curiosity, or to technical botanists, since no great claim to beauty can be made. It and its associated species have provided a field of controversy for taxonomists and morphologists, but the economic botanists have not been greatly disturbed by the arguments.	Probably serves as food and cover for some of the animals of its environment, and may conceivably make some tangible contribution toward lessening the erosive effects of wave- and tide-simulated water, in its surroundings.

nature IN THE SCHOOL

During the year 1873, the famous scientist Louis Agassiz established a summer school on the island of Penikese, off the New England coast. In this marine environment, one of the greatest teachers of biology taught a group of from fifty to sixty adults.

Many of his study group returned to homes that were far-removed from an intertidal strip, to prepare books to be used as guides in the teaching of biology. Much of the material that appeared in the resulting books concerned the organisms observed and studied on the Penikese intertidal strip; and, perhaps because of this, there are many schools today that, for study purposes, use marine plants and animals similar to those studied at Agassiz' summer school.

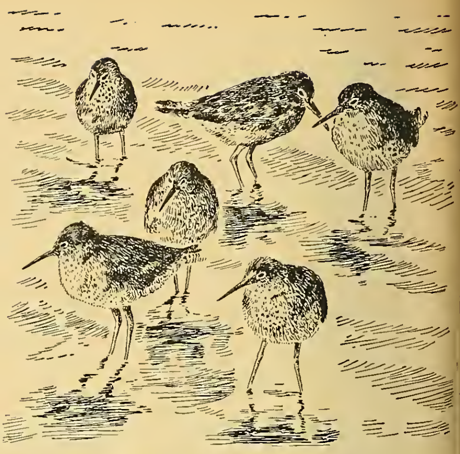
Biological supply houses, also, offer seaweeds similar to those studied by the Agassiz group in 1873; and, indeed, the study of seaweeds in school is currently recognized as appropriate, even if such a study results in the neglect of the locally available algae.

While biological houses can supply excellent marine material for study in those schools that are far removed from tidal strips, there are probably many schools with access to the sea that are not making the best use of the available opportunities. Here, then, are some study suggestions for classes or individuals.

Select some rock, pool, or unit of sandy beach, and keep a record of the changes in its population during the course of a single year. Record the temperature of the area at regular intervals through a twenty-four-hour cycle, to show variations between low and high tides. Make a record of the length of time a selected area is submerged, and the length of time during a day when it is not touched by sea water. Note the effect of submergence and exposure on the bases and tips of the marine algae that are present. Make a survey of the animals present at the surface of the plant cover surface, and yet another of those found close to the bottom of the plant cover. In what ways do they differ?

From direct observation of the material found at one locality, indicate which of the organisms present are annuals, and which are longer-lived. If special reproductive structures are to be seen on parts of the plants, make a record of the months in which they are the most obvious. If possible, make accurate laboratory studies of the events that take place in the reproductive structures.

Observe whether animals feed on the algae in the test area, and collect specimens that have been partly eaten. Examine the plants and their closely associated animals, to ascertain whether the associations are constant or varied. Do shore birds, feeding along a strip of land covered by marine algae, confine their search for food to open and exposed rocks, or to algae-covered earth? Make a study of any peculiar feeding habits of the local shore birds, and the relation of these habits to the local marine algae.



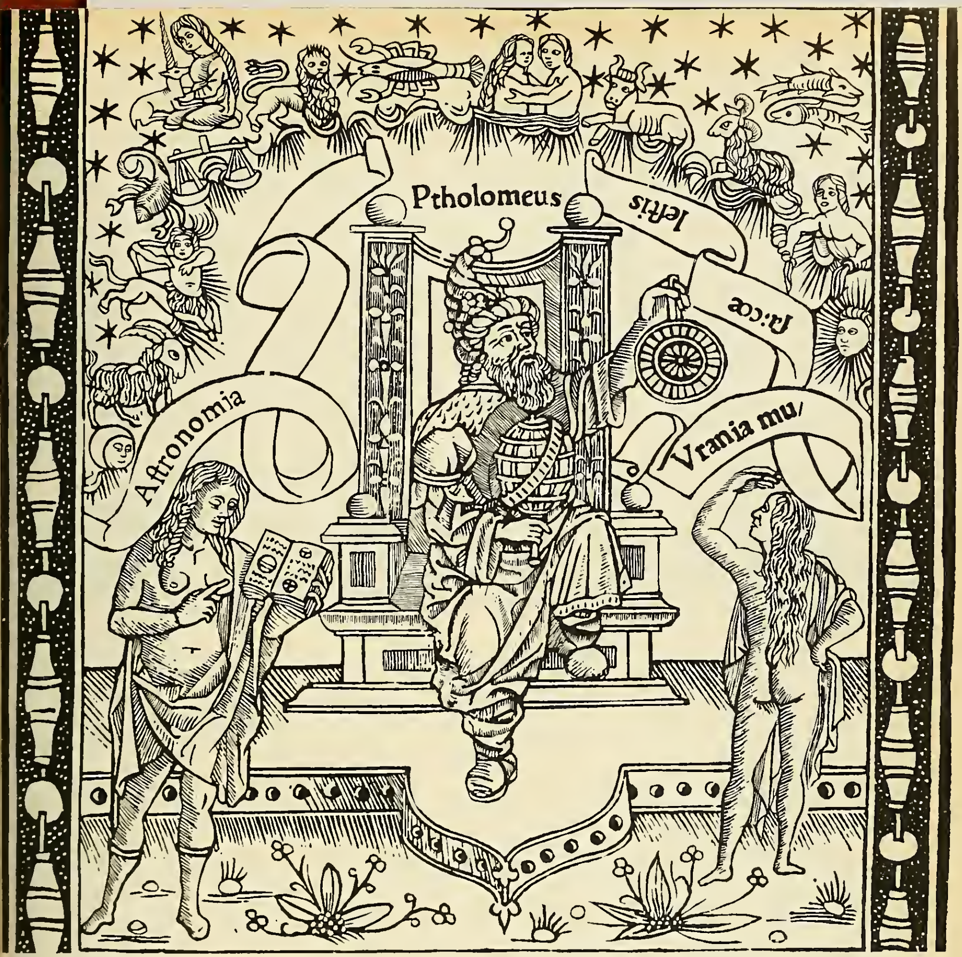
Feeding habits of shore birds may relate to local marine algae.

Make a herbarium of local marine algae, if such plants are available. These plants may often fasten themselves to herbarium sheets simply by means of the mucilage that is found on them. If the herbarium sheet is submerged in a large pan partly filled with water, and the algae floated into position over the paper, the surplus water may be drawn off and the algae allowed to dry "in position" on the sheet. This permits the arrangements of strands of fine algae, so that the strands do not "bunch up" and form an unsightly mass. Some students have employed the technique of covering the wet algae, in proper position, with waxed paper. The mucilage will not stick to the waxed paper, and the material may then be dried through the mounting paper.

After a list of the local marine algae has been made, consult the available laboratory manuals to ascertain which of the local species have been considered. The student may be surprised to find how few of the conspicuous local species are represented in such a list. He may also be surprised to learn of the considerable detail devoted to *other* species. A study such as this is certain to suggest areas in which individual research will be highly profitable and of extraordinary interest.

It seems reasonable, therefore, to suggest that a school biology class should be prepared to depart from the routine prescribed by texts and laboratory manuals at least once, to explore a virgin field. The study of the marine algae and their associates will offer a rich opportunity in this respect.

The graceful positions assumed by many of the marine algae might provide inspiration for artistic young students. Particularly striking specimens may be photographed, and used for making designs of a most attractive appearance. The elastic nature of the average marine algae, which can survive the whipping and lashing of storm waves, may also suggest that survival of life is sometimes best achieved by a course of non-resistance to superior forces . . . up to a certain point, at least!



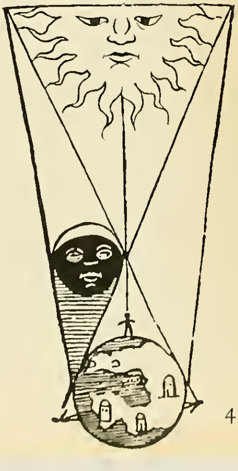
SKY REPORTER

By Simone Daro Gossner

IN ALL ITS COMPLEXITY, the system of Eudoxus' homocentric spheres (*see* February article) failed to account for one observed fact, the inequality of the seasons. The astronomer Callippus, born in Cyzicus, *ca.* 330 B.C., had become aware of this discrepancy and attempted to modify Eudoxus' theory in order to account for the length of the seasons as well. His solution was merely to increase the total number of spheres, which he brought to thirty-three. The famous Aristotle may have worked with Callippus for a while: although he shared the latter's acceptance of homocentricism, his approach was different.

Aristotle believed that all celestial motions obey a single moving force and, therefore, that all must be interrelated. In other words, instead of considering a separate group of spheres for each of the planets, as did Eudoxus, Aristotle held that the spheres of Mars, for example, are subject to all the motions of Jupiter's spheres, which in turn are connected with those of Saturn. Since, however,

Claudius Ptolemy is depicted in a woodcut, *above*. His explanation of a solar eclipse is reproduced below.



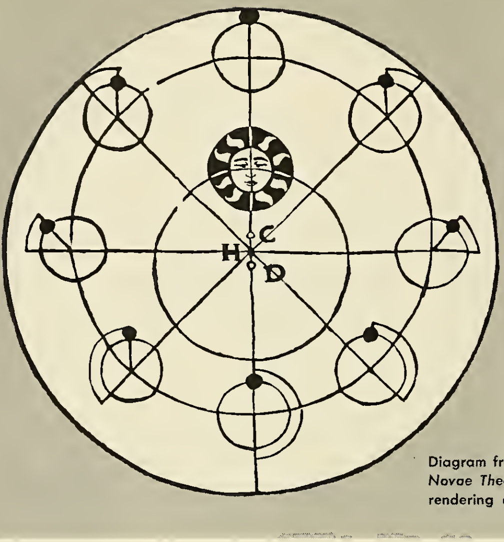
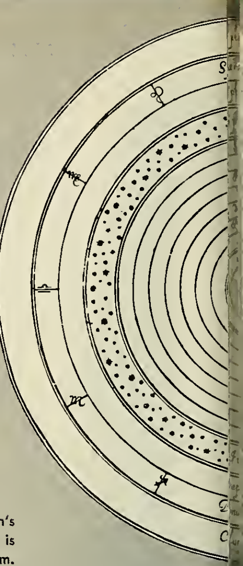


Diagram from Georg Purbach's *Novae Thearicae Planetarum* is rendering of Ptolemaic system.



there is no evidence of such connection in the appparent motions of these planets, he had to introduce compensating spheres to eliminate spurious motions. This needlessly cumbersome system required fifty-seven spheres!

There was another basic difference between the cosmologies of Eudoxus and Aristotle. The former conceived homocentric spheres as purely mathematical representations (much in the same way that we think of gravitation, for example). Aristotle, on the contrary, thought of these spheres as physical entities. To him they were hollow bodies—made of crystal, since they were transparent.

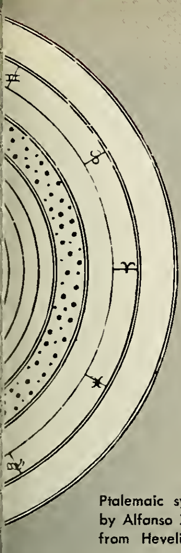
IN spite of the extraordinary influence of Aristotle's teachings, which would be felt for nearly two thousand years, a few astronomers of his time had come to understand that the whole notion of homocentricism was incompatible with observational evidence. In particular, they had correctly interpreted the variable brightness of Venus and Mars as being caused by a corresponding variation in the distance of these planets from earth. One of them, Heracleidus Ponticus, went so far as to suggest that Venus revolves around the sun. A few decades later, *ca.* 280 B.C., Aristarchus of Samos designated the sun as the center of *all* planetary motions—including that of the earth. This precursor of Copernicus did not fare too well, unfortunately. His views were so contrary to the evidence of the senses that he had only a small following [after all, do *you* feel the earth rotating and traveling in space?]. The next centuries saw a complete return to the concept of a fixed earth.

The four hundred years following Aristarchus represent the crucial period during which the system that would bear the name of Ptolemy slowly began to crystallize. The observations of Hipparchus—who lived at Rhodes in the second century B.C.—had revealed details of celestial motions that could no longer be explained by the homocentric theory. The astronomers of that period did not think of abandoning the concept of *circular* orbits, but they accounted for the varying distances of planets by offsetting these orbits with respect to the earth. "Loops" in the apparent motions of planets were explained by combining two or more circular motions. Various refinements were introduced over the years, until Ptolemy organized the theories of his predecessors into one coherent system and described it in his monumental work, commonly known as the *Almagest.*

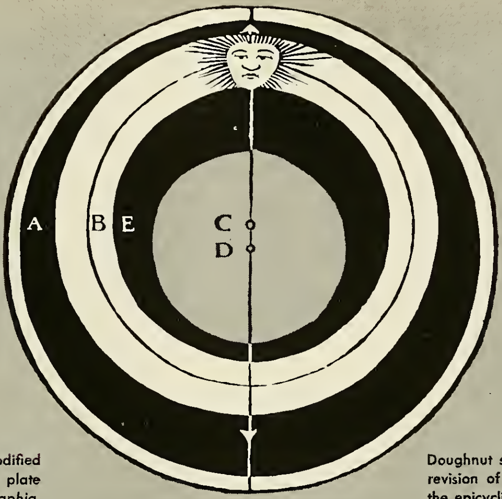
History tells us little about Claudius Ptolemy beyond the fact that he was of Greco-Egyptian origin, and that he lived at Alexandria in the second century of the Christian Era. He was an astronomer, mathematicia and geographer of great ability. H explanation of planetary motion which we call the Ptolemaic system, extremely complex.

IN his time, the distances from eart of the various planets, the sun an the moon, were not well enoug known for Ptolemy to place them i their correct sequence—supposing, course, that the earth was at the ce ter of the system. He placed them i stead in increasing order of the apparent periods of revolution, viewed from the earth. Thus, from t earth outward, the sequence read: t moon, Mercury, Venus, the sun, Mar Jupiter, and Saturn. This arrang ment ignores the fact that Mercur and Venus can, at times, be farth away from the earth than is the su It is true that this fact had been su mised by some of Ptolemy's predece sors, but the latter's strict adheren to geocentricism ruled out the poss bility. In Ptolemy's sequence, Ven and Mercury are called inferior pla ets, meaning that they are closer the earth than is the sun; conversel Mars, Jupiter, and Saturn are calle superior planets. These terms are sti in use today, even though they ha lost their Ptolemaic significance.

The principles of the Ptolema system can be illustrated best in t case of one of the superior planets (i



Ptolemaic system, as modified by Alfonso X, appears in plate from Hevelius' *Selenographia.*



Doughnut shape is Renaissance revision of Ptolemy's theory of the epicyclic motion of the sun.

lustration at left, *above*). The planet (small black dot) is thought to revolve with constant speed around a small circle, called the *epicycle*. The center of the epicycle, in turn, is assumed to revolve around a larger circle (with its center at C) called the *deferent*. The earth is located at D: thus the deferent is off-center with respect to the earth, and is sometimes called the *eccentric* for that reason. In order to conform with data of observation, the center of the epicycle should move at varying speed along the deferent. This, however, is contrary to the principle of uniform speed so dear to the ancients; principle and observation are reconciled by the introduction of still a third circle, called the *equant* (outermost circle, with center at H), with the assumption that a point on the line joining H to the center of the epicycle moves along the equant at constant speed. Inasmuch as H does not coincide with the center of the deferent, the resulting speed of the epicycle along the deferent becomes variable.

Although the Ptolemaic system was rooted in the cumbersome concept of a completely static earth, it accounted satisfactorily for observed planetary motions within the limits of accuracy of the epoch. The loops in apparent orbits were explained by motion along an epicycle. The variable speed along the orbit was justified by the equant. Other phenomena, such as eclipses, were understood correctly, as the diagram at the foot of page 45 serves to demonstrate.

DURING the Dark Ages, European science underwent a steady decline as barbarian invasions isolated the scholars there from the major sources of classic tradition. Astronomy reverted to empirical concepts and astrological nonsense. Fortunately, the continuity of Greek science was assured through the brilliant Arab civilization that flourished during that period. Toward the middle of the twelfth century, European scholars began to rediscover many of the important Greek astronomical works in their Arabic translations. Among them, Gerard of Cremona published a translation of Ptolemy's *Almagest* at Seville in 1175. A century later, King Alfonso X of Castile published a new set of astronomical tables, based on a modification of the Ptolemaic system, which sought to account for the observed, slow displacement of the celestial pole (*see* illustration at center of page, *above*).

Given this new impetus, Ptolemaic astronomy flourished again and reached its greatest moments in the fifteenth and sixteenth centuries, particularly at the hands of Georg Purbach (1423-1461) of Vienna and his disciple Johann Müller (1436-1476) of Königsberg, who became known under the name Regiomontanus. The invention of the printing press in about 1440 permitted unprecedented diffusion of their works. In fact, Regiomontanus himself established his own publishing house. The numerous editions of astronomical treatises of that period bear witness to the considerable popular interest these works seem to have aroused.

From the physical standpoint, it appears that Ptolemy was reluctant to discard the views of Aristotle concerning material spheres. He tried, not too successfully, to give a physical equivalent to his mathematical epicycles and deferents, by assuming that the motions along those circles are caused by the existence of an ethereal fluid encased in solid orbs—one rolling within the other. This idea seemed hardly acceptable because the orbs pertaining to various planets would necessarily overlap and it was thought inconceivable that the same fluid could impart different motions to different objects. Renaissance astronomers, however, removed this difficulty by substituting doughnut-shaped bodies for the spherical orbs. In this way, the system belonging to each planet could be kept from penetrating any of the others. A sixteenth-century representation of this is shown at right, *above*, in the case of the sun (white epicycle overlapping black deferent).

THE SKY IN MARCH

From the Almanac:

Full Moon	March 2, 8:35 A.M., EST
Last Quarter	March 9, 9:58 P.M., EST
New Moon	March 16, 1:51 P.M., EST
First Quarter	March 23, 9:49 P.M., EST

The sun will be at the vernal equinox on March 20 at 3:32 P.M., Eastern Standard Time. On that date, spring will begin in the Northern Hemisphere.

For the visual observer:

Mercury, in the morning sky, will reach its greatest western elongation on March 20, and will be favorably placed for observation for a few days on either side of that date. It will rise in the southeast at about 5:30 A.M. on March 1, and at 5:00 A.M. on March 15 and 31.

Venus, in Pisces, will be seen as an evening star throughout the month of March. It will reach its greatest brilliancy (—4.3 magnitude) on March 5, and will be a very conspicuous object high above the western horizon in early evening. Its brightness will fade gradually from —4.2 magnitude on March 15 to —3.7 on March 31. The planet will set at approximately 9:30 P.M. on March 1, at 9:00 P.M. on March 15, and at 8:00 P.M. on March 31.

Mars, in Gemini, will be nearly overhead at dusk during the entire month. It will set in the northwest at about 3:15 A.M. on March 1, at 2:30 A.M. on March 15, and at 2 A.M. on March 31. Its brightness will continue to decrease from +0.3 magnitude on March 1 to +0.9 on March 31.

Jupiter, in the morning sky (—1.6 magnitude), will be found between Sagittarius and Capricornus, and will stand out in the southeastern sky at sunrise. The planet will rise at approximately 4:40 A.M. on March 1, at 3:40 A.M. on March 15, and at 2:50 A.M. on March 31.

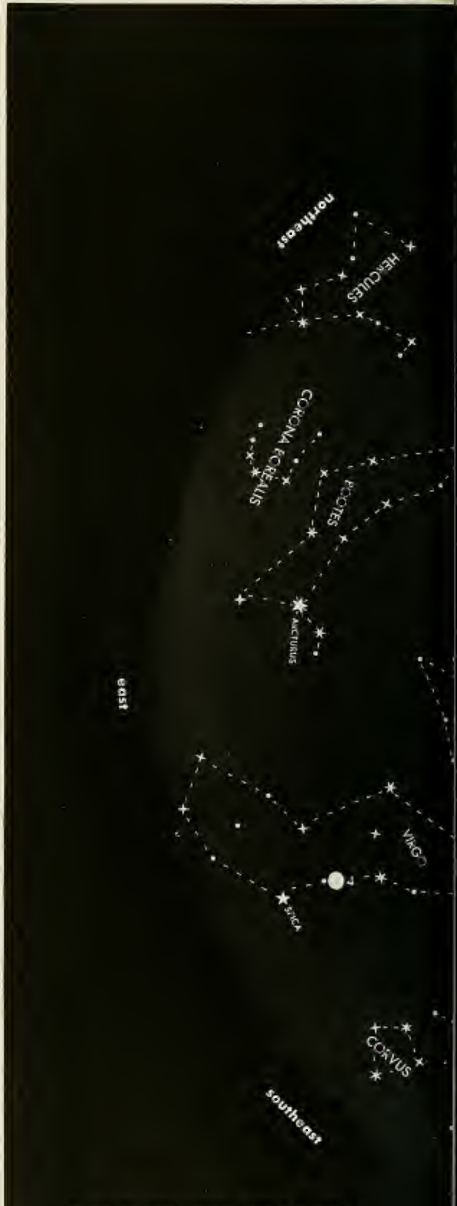
Saturn, in Sagittarius (+0.9 magnitude), will also be in the morning sky, a few degrees west of Jupiter—with which it will make a noteworthy pair. These two planets will rise a few minutes apart—Saturn preceding—during the entire month of March (see times above).

Lunar Eclipse:

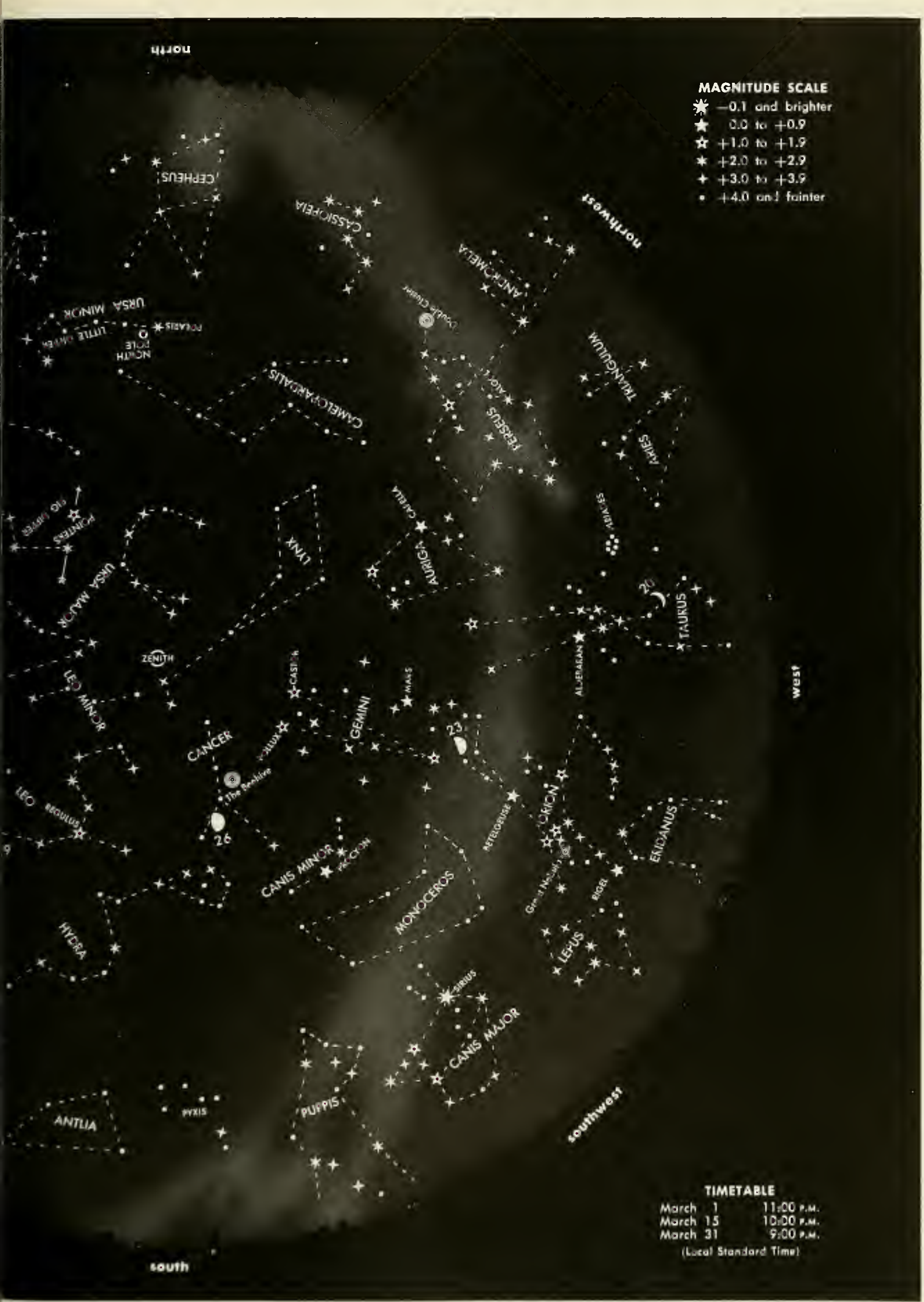
An extensive partial eclipse of the moon will take place during the early morning hours of March 2. Observers on the east coast will get only a glimpse of the penumbral phase, which will start at 5:32 A.M., EST, with an almost imperceptible lessening of the moon's brightness. In those locations, unfortunately, the moon will set a few minutes before the beginning of the umbral phase. Elsewhere in the country, observers will be able to see at least the first encroachment of the earth's shadow on the disk of the moon (5:51 A.M., CST, and the equivalent in other time zones). Most favored will be the West Coast, where the maximum eclipse will be seen at 5:28 A.M., PST. But even there, the moon will set partially eclipsed.

The magnitude of this eclipse at maximum phase will be 0.8. This means, by definition, that eight-tenths of the lunar *diameter* will be covered by the earth's shadow, and is the conventional way of expressing the extent of an eclipse. Observers with a small telescope can follow the progress of the shadow across the various features of the lunar surface and record the time of their disappearance.

On the preceding pages, MRS. GOSSNER offers the third in her 1961 series on the growth of cosmological concepts.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.


north
CEPHEUS
CASSIOPEIA
northwest
ANDROMEDA
Double Cluster
URSA MINOR
LITTLE DIPPER
POLARIS
NORTH POLE
CAMELOPARDALIS
ALGOL
PERSEUS
TRIANGULUM
ARIES
POINTERS
BIG DIPPER
URSA MAJOR
LYNX
CAPELLA
AURIGA
PLEIADES
20
TAURUS
ALDEBARAN
west
ZENITH
LEO MINOR
CASTOR
POLLUX
GEMINI
MARS
23
CANCER
The Beehive
26
LEO
REGULUS
CANIS MINOR
PROCYON
MONOCEROS
BETELGEUSE
ORION
Great Nebula
RIGEL
ERIDANUS
LEPUS
HYDRA
SIRIUS
CANIS MAJOR
PUPPIS
PYXIS
ANTLIA
southwest
south

MAGNITUDE SCALE

- −0.1 and brighter
- 0.0 to +0.9
- +1.0 to +1.9
- +2.0 to +2.9
- +3.0 to +3.9
- +4.0 and fainter

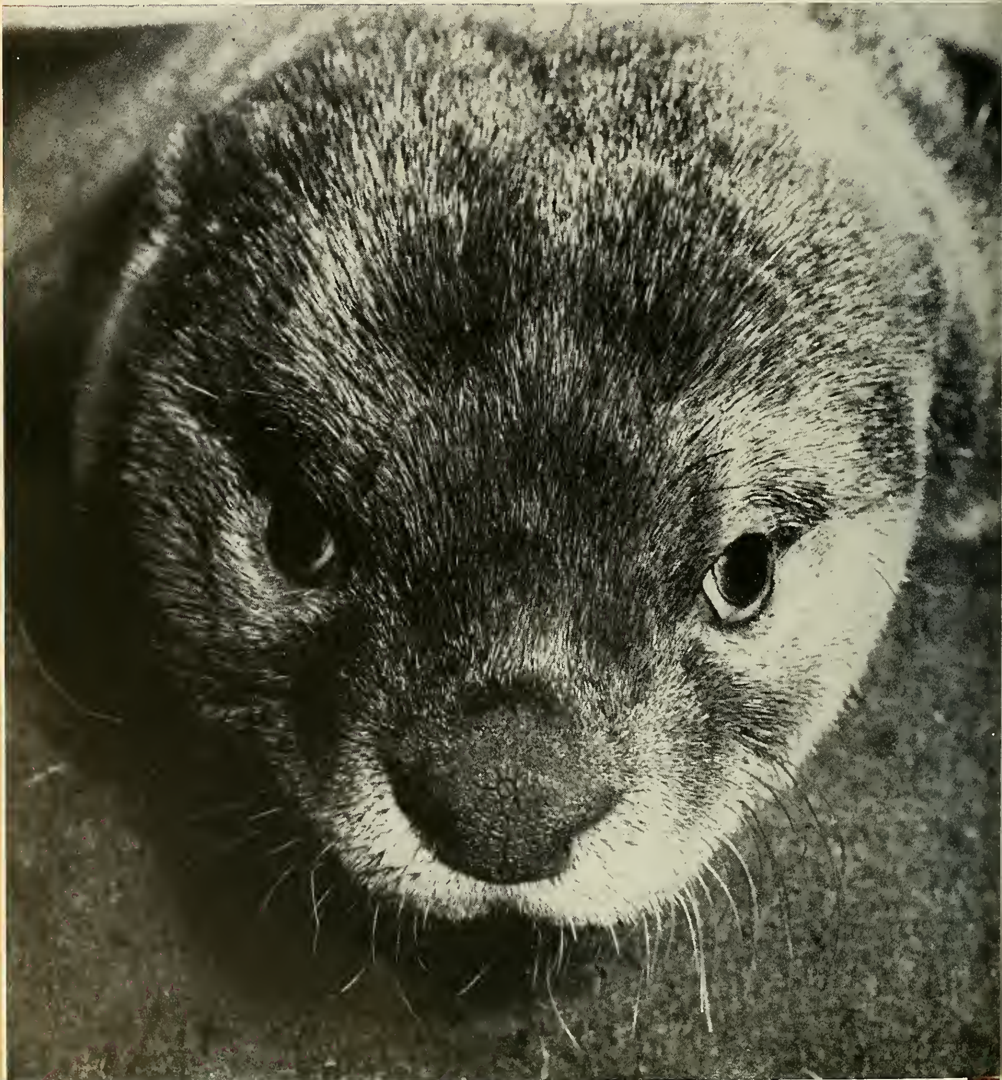
TIMETABLE

March 1	11:00 P.M.
March 15	10:00 P.M.
March 31	9:00 P.M.

(Local Standard Time)

The Lives and Times of Mij and Edal

Young otters from Iraq and Nigeria adapt to Highland waters



By Gavin Maxwell

EARLY IN THE NEW YEAR of 1956, I traveled with Major Wilfred Thesiger to spend two months or so among the little-known marshmen, or Ma'dan, of southern Iraq. By then it had crossed my mind, though with no great emphasis, that I should like to keep an otter and that my isolated home in the western Highlands—ringed by water just a stone's throw from its door—would be an eminently suitable spot for this experiment. I mentioned this casually to Wilfred soon after the outset of our journey and he, as casually, replied that I had better get one in the Tigris marshes before I came home, for there otters were as common as mosquitoes, and were often tamed by the Arab "people of the reeds."

A few days after our marsh journey had ended, I went to Basra—where the British Consul very kindly took me in as a guest—to collect and answer mail from home. As I should have expected, the mail was late. Returning to the Consulate one afternoon, I found that the mail had arrived at last. I carried it to my bedroom to read and there, squatting on the floor, were two marsh Arabs; beside them lay a well-filled sack that squirmed from time to time.

They handed me a note from Thesiger. "Here is your otter, a male and weaned. . . . Give Ajram a letter to me saying it has arrived safely. . . ."

With the opening of that sack began a phase of my life that has not yet ended and may, for all I know, not end before I do. It is, in effect, a thralldom to otters.

The creature that emerged, not greatly disconcerted, from this sack on to the spacious tiled floor of the Consulate bedroom did not at that moment resemble anything so much as a very small medievally conceived dragon. From the head to the tip of the tail he was coated with symmetrical pointed scales of mud armor, between whose tips was visible a soft velvet fur like that of a chocolate-brown mole. He shook himself, and I half expected this aggressive camouflage to disintegrate into a cloud of dust but it remained unaffected by his maneuver, and in fact it was not for another month that I contrived to remove the last of it and see him, as it were, in his true colors.

MIJ, the first of the author's pet otters, was found in Iraq, flown to Scotland.

MIST-HUNG MOUNTAINS shadow author's dinghy, which is moored in shallows of the island-studded west Scotland bay, opening out to wild Atlantic beyond.

FOR the first twenty-four hours, Mij—whom I named after a local sheik—was not hostile or friendly; he was simply aloof and indifferent, choosing to sleep on the floor as far from my bed as possible, and to accept food and water as though they were things that had appeared before him without human assistance. The food presented a problem, for it did not immediately occur to me that the marsh Arabs had almost certainly fed him on rice scraps supplemented only by such portions of fish as are inedible to humans. The Consul-General sent out a servant to buy fish, but this servant's return coincided with a visit from Robert Angorly, the Crown Prince's game warden, who entertained a passionate interest in natural history. Angorly told me that none of the fishes that had been bought was safe for an animal, for they had been poisoned with digitalis, which, though

Toboggan slide on hill, sloping down to brook at the bottom, was a favorite play site of the Iraqi otter that so quickly adapted to his Scottish home.

harmless to a human in this quantity, he felt certain would be dangerous to a young otter. He offered to obtain me a daily supply of fish that had been taken with nets, and every day thereafter he brought half a dozen or so small reddish fish from the Tigris. These Mij consumed with gusto, holding them upright between his fore-paws, tail end uppermost, and eating them with five crunches of the left-hand side of the jaw alternating with five crunches on the right.

The otter and I enjoyed the long-suffering Consul-General's hospitality for a fortnight. The second night, Mij came on to my bed in the small hours and remained asleep in the crook of my knees until the servant brought tea in the morning. During that day, he began to lose his apathy and take a keen—much too keen—interest in his surroundings. I fashioned a body-belt for him and took him on a lead to the bathroom, where for a half-hour he went wild with joy in the bath water, plunging and rolling in it, shooting up and down the length of the bath underwater, and making enough slosh and splash for a hippo. This, I was to learn, is a characteristic of otters; every drop of water must be, so to speak, extended and spread about the place; a bowl must be overturned, or, if it will not overturn, be sat in and sploshed in until it overflows. Water must be kept on the move and made to do things; when static, it is as wasted and provoking as a buried talent.

There is a patron saint of otters, St. Cuthbert (the eider duck, too, shares his patronage), and there exists an eyewitness account of his converse with them:

"As was his habit, at night while other men were taking their rest, Cuthbert would go out to pray; and after long vigils kept far into the night, he would come home when the hour of common prayer drew near. One night, a brother of this same monastery saw him go silently out, and stealthily followed on his track, to see where he was going or what he would do. And so he went out from the monastery and, his spy following him, went down to the sea, above which the monastery was built: and wading into the depths till the waves swelled up to his neck and arms, kept his vigil through the dark with chanting voiced like the sea. As the twilight of dawn drew near, he waded back up the beach, and kneeling there, again began to pray: and as he prayed, straight from the depths of the sea came two four-footed beasts which are called by the common people otters. These, prostrate before him on the sand, began to busy themselves warming his feet with pantings, and trying to dry them with their fur; and when this good office was rendered, and they had his benediction they slipped back again beneath their native waters. He himself returned home, and sang the hymns of the office with the brethren at the appointed hour."

It is apparent to me now, that whatever other saintly virtues St. Cuthbert possessed, he well merited canonization by reason of his forbearance alone. I know all about being "dried" by otters. I have been dried by them

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Mr. Maxwell is a free-lance writer, portrait painter, and naturalist, from whose book, *Ring of Bright Water*, just published by E. P. Dutton and Co., this otter history is excerpted.

more times than I care to remember. Like everything else about otters, it takes place the wrong way round, so to speak. When one plays ball with a puppy, one throws the ball and the puppy fetches it back and then one throws it again; it is all comparatively restful and orderly. But when one plays ball with an otter the situation gets out of hand from the start; it is the otter who throws the ball—to a remarkable distance—and the human who fetches it. With the human who at the beginning is not trained to this, the otter is fairly patient, but persistent and obstinate refusal meets with reprisals. The same upside-down situation obtains when being dried by otters. The otter emerges tempestuously from the sea or the river or the bath, as the case may be, carrying about half a gallon of water in its fur, and sets about drying you with a positively terrifying zeal and enthusiasm. Every inch of you requires, in the view of a conscientious otter, careful attention. The otter uses its back as

Rock pool in a sheltered, seaside bay supplied Mij with eels to eat, small fish to chase, and seaweed to play with. In this environment, otter relaxed into a complete freedom of movement, returning to the author's house only to sleep.

Although all four feet were webbed, Mij was remarkably dexterous, would spend hours juggling small objects, or rolling them easily between forepaws.

the principal towel, and lies upon it while executing a series of vigorous, eel-like wriggles. In a surprisingly short space of time, the otter is quite dry except for the last four inches of its tail, and the human being is soaking wet. It is no use going to change one's clothes; in a few minutes the otter will come rampaging out of the water again, zealously intent upon its mission of drying people.

I have but little doubt what the good brother of Coldingham monastery really saw. St. Cuthbert had been praying at the water's edge, not, as the brother thought (it was, one must bear in mind, night, and the light was poor) up to his neck in the waves; and it was entirely the condition of the saint's clothing after he had been dried by the otters that led the observer to deduce some kind of submarine devotion. Clearly, too, it was an absolution rather than a simple benediction that the now shivering and bedraggled saint saw fit to bestow upon his four-footed tormentors.

While otters have a special vocation for drying human beings, they will also dry other objects, most particularly beds, between the sheets, all the way from the pillows to the bed foot. A bed dried by this process is unusable for a week, and an otter-dried sofa is only tolerable in the heat of summer. I perceive why St. Cuthbert required the ministrations of the eider ducks and the warm down of their breasts: the unfortunate man must have been constantly threatened with an occupational pneumonia.

This aspect of life with an otter had never really struck me before I brought Mij to the Highlands. In London, our first stop, one could run the water out of the bath, and by using a monster towel could render him comparatively harmless before he reached the sitting room. But at Camusfeàrna, with the sea a stone's throw on one side and the bourn on the other, I have found no satisfactory solution beyond keeping the bedroom door closed and turning, as it were, a blind posterior to wet sofas and chairs.

The scant zoological literature that
had accompanied me to Iraq
made it plain that the only known
otter of the Mesopotamian marshes
was the Persian subspecies of the
common European otter, *Lutra lutra*.
In a village of the marshes between
the Tigris and the Persian frontier I
had bought two otter skins. Both
were, apart from any possible scien-
tific interest, objects of fascination
for they had been "case" skinned, th
whole carcass having been removed
without a single incision, through th
mouth. One of these skins belonged t
the Persian subspecies; the other
contrast heightened by juxtaposition
was plainly of Mij's race, a muc
larger and darker creature, whose fu
was short and shiny and the color o
milkless chocolate.

While in London on my way to th
Highlands, I telephoned to the Brit
ish Museum (Natural History) i
Cromwell Road, and the same after
noon Mr. Robert Hayman arrived a
my flat to examine the two skins an
Mij. There is in the serious zoologica
world an unwillingness for committa
that must rival the most cautious o
consulting physicians. Hayman wa
far too competent a zoologist, far to
encyclopedic in his knowledge, t
have been unaware in those first m
ments that he was looking at a ski
and a living animal from a habit
that made the race quite unfamiliar t
him. But he did not betray it. He too
such measurements as Mij would pe
mit, examined him closely, peered
his formidable array of teeth, an
left, bearing the two skins for compa
ison with a Museum series.

In due course, after the precis
painstaking processes of the tax
nomic world, Mij's new race was pr
claimed. Hayman summoned me
the Museum to see the cabinets of o
ter skins from all over Asia, whe
the Mij-like one of mine lay, unl
beled and conspicuously differi
from any other, in a drawer by itsel
but in apposition to its nearest rel
tives. These, various subspecies
Lutrogale, a short-coated otter with

flat underside to the tail, ranged over most of eastern Asia; according to their geographical race they were of a variety of hues from pale sandy to medium brown, but none had been recorded west of Sind, in India, and none resembled mine in color.

There are very few people, and even fewer amateur zoologists, who stumble upon a sizable mammal previously unknown to science; in the nursery world of picture books of birds and beasts the few who had given their own names to species—Steller's eider and sea eagle, Sharpe's crow, Humboldt's woolly monkey, Meinerzthagen's forest hog, Ross's snow goose, Grant's gazelle, Père David's deer—had been surrounded for me with an aura of romance. Now, when Hayman suggested that the new otter should bear my name, something small and shrill from the nursery days shouted inside me that I could be translated into the hierarchy of my early gods and wear, however perilously, the halo of a creator. ("Can I have it for my own?" we used to ask when we were small. "For my *very* own?" Here, surely, was an animal of my very own, to bear my name; every animal that looked like it would always bear my name for ever and ever, unless some odious taxonomist of the future, some leveler, some jealous, dusty scribe of the backroom and the skeletons, were to plot against me and plan the destruction of my tiny, living memorial.)

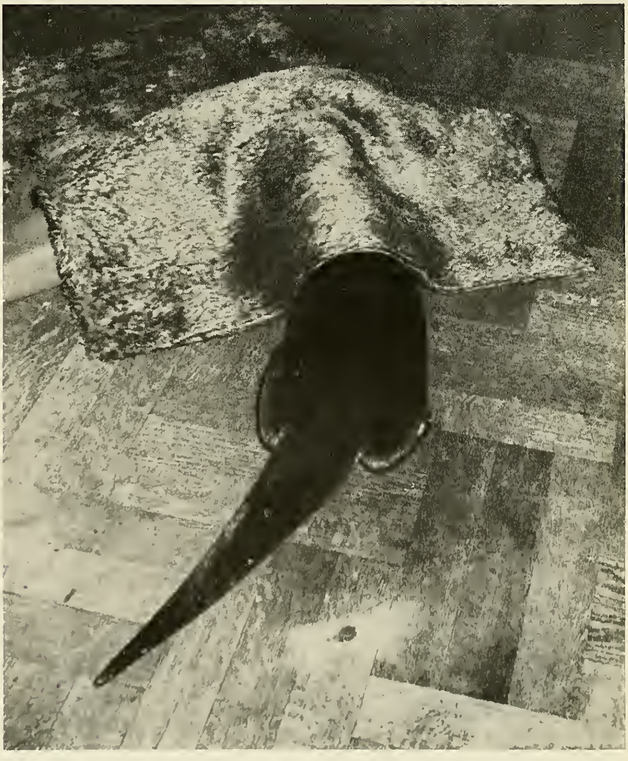
So Mij and all his race became *Lutrogale perspicillata maxwelli*, and though he is now no more, and there is no ostensible proof that there is another living specimen in the world, I had realized a far-off childish fantasy, and there was a Maxwell's otter.

WHEN I think of early summer in the western Highlands, a single enduring image comes forward—that of wild roses against a clear blue sea. They are not the pale, anemic flowers of the south, but a deep, intense pink that is almost a red; it is probably the only flower of that color, and it is the only flower that one sees habitually against the background of the ocean, free from the green stain of summer.

Into this bright landscape Mij moved and took possession with behavior that communicated delight as clearly as any articulate speech could have done, his alien but essentially appropriate entity occupied and dominated every corner of it, so that he became for me the central figure among the host of wild creatures with which I was surrounded. The waterfall, the bourn, the white beaches and the islands—his form became the familiar foreground to them all.

At the beginning, while I was still imbued with the caution and forethought that had so far gone to his tending, Mij's daily life followed something of a routine; this became, as the weeks went on, relaxed into a total freedom at the center point of which my house remained Mij's holt, the den to which he returned at night, and in the daytime when he was tired. But this emancipation, like most natural changes, took place so gradually and unobtrusively that it was difficult for me to say at what point the routine had stopped.

Mij slept in my bed and would wake with bizarre punctuality at exactly twenty past eight in the morning. Having woken, he would come up to the pillow and nuzzle my face and neck with small attenuated squeaks that seemed to me of pleasure and affection. If I did not rouse myself very soon, he would set about getting me out of bed. This he did with what impressed me as the business-like, slightly impatient efficiency of a nurse dealing with a difficult child. He began by going under the bedclothes and moving rapidly up and down the bed with a high-hunching, caterpillar-like motion that gradually untucked the bedclothes from beneath the sides of the mattress. This achieved, he would redouble his efforts at the foot of the bed, where the sheets and blankets had a firmer hold. When everything had been loosened up to his satisfaction, he would flow off the bed on to the floor—except when running on dry land the only appropriate word



FAVORITE indoor game played by Mij involved "hiding" under a carpet until a human passed near and then shooting out with apparently triumphant squeak.

Second otter in author's home was Edal, born in Nigeria, whose forepaws were unwebbed and monkey-like. With them she was able to peel hard-boiled eggs and even pick pockets Unlike Mij, Edal at first ventured only in shallow waters

for an otter's movement is flowing; they pour themselves, as it were, in the direction of their objective—take the bedclothes between his teeth, and, with a series of violent tugs, begin to yank them down beside him. Left thus comfortless and bereft both of covering and of dignity, there was little option but to dress, while Mij looked on with what seemed to me an all-that-shouldn't-really-have-been-necessary-you-know sort of expression. Otters usually get their own way in the end; they are not dogs, and they coexist with their fortunate human hosts rather than being owned by them.

In the sea, Mij achieved his true, breath-taking powers; until he came to Scotland he had never swum in deep waters, for the lakes and lagoons of his native marshes are rarely more than a fathom or two deep. He would swim beside me as I rowed in a little dinghy, and in the glass-clear waters of Camusfeàrna Bay, where the white shell sand alternates with sea tangle and outcrops of rock, I could watch him as he dived down, down, down through fathom after fathom to explore the gaudy sea forests at the bottom with their flowered shell glades and mysterious, shadowed caverns. He was able, as are other otters, to walk on the bottom without excessive buoyance, for an otter swims habitually underwater and does not dive with full lungs, depending for oxygen—we must presume, in the absence of knowledge—upon special adaptations of the circulatory system. The longest that I ever timed Mij below the surface was almost six minutes, but I had the impression that he was in no way taxin his powers, and could greatly hav exceeded that time in emergency Normally, however, if he was not engrossed, he would return to the surface every minute or so, breaking i for only a second, with a forward diving roll like that of a porpoise. Swimming at the surface, as he did if h wanted to keep some floating objec in view, he was neither very fast no graceful, using a laboring dog paddl in amazing contrast to his smooth darting grace below water. For hour he would keep pace with the boat, appearing now on this side and now o that, sometimes mischievously seizin an oar with both arms and draggin on it, and from time to time bouncin

inboard with a flurry of water, momentarily recalled to his mission of "drying" any person at hand.

Mij himself caught a number of fish on his daily outings; and week by week, as his skill and speed grew, their size and variety increased. In the bourn he learned to feel under stones for eels, reaching in with one paw and averted head. Meanwhile, I learned to turn over the larger stones for him, so that after a time he would stand in front of some boulder too heavy for him to move, and chitter at me till I came and lifted it for him. Often, as I did this, an eel would streak out from it into deeper water and Mij would fire himself after it like a brown torpedo beneath the surface. Near the edge of the tide he would search out the perfectly camouflaged flounders until they shot off with a wake of rising sand grains like smoke from an express train. Farther out in the bay he would kill an occasional sea trout; these he never brought ashore, but ate them while he was treading water, and I thought a little wistfully of the Chinese who are said to employ trained otters to fish for them. Mij, I thought, with all his delightful camaraderies, would never offer me a fish. I was wrong, but when at last he did so it was not a sea trout but a flounder. One day he emerged from the sea on to the rock ledge where I was standing and slapped down in front of me a flounder a foot across. I took it that he had brought this for congratulation, for he would often bring his choicer catches for inspection before consuming them, so I said something encouraging and began to walk on. He hurried after me and slammed it down again with a wet smack at my feet. Even then I did not understand, assuming only that he wished to eat in company, but he just sat there looking up and chittering at me. I was in no hurry to take the gesture at its face value. One of the most aggressive actions one can perform to a wild animal is to deprive it of its prey, but after perhaps half a minute of doubt, while Mij redoubled his invitation, I reached down slowly and cautiously for the fish, knowing that Mij would give me vocal warning if I had misinterpreted him. His expression seemed one of plainest approval when I picked it up and began a mime of eating it; then he plunged off the rock into the sea and sped away a fathom down in the clear water.

WATCHING Mij in a rough sea—and the equinoctial gales at Camusfeàrna produce very rough seas indeed—I was at first sick with apprehension, then awed and fascinated, for his powers seemed little less than miraculous. During the first of the gales, I remember, I tried to keep him to the rock pools and the

EDAL's silvery colored head and her yellow-white throat and chest differed sharply from Mij's darker hue. Pools in rocks supplied her with butterfish.

For the most part, Edal preferred to keep her feet on or near bottom of pool, and would not be lured into deep water.

When spray from the garden hose was played upon her, she reacted with enthusiasm, slapping at drops with her forefeet.

more sheltered corners, but one day his pursuit of some unseen prey had taken him to the seaward side of a high, dry reef at the very tide's edge. As the long undertow sucked outward he was in no more than an inch or two of marbled water with the rock at his back, crunching the small fish he had caught; then, some forty yards to seaward of him I saw a great snarling comber piling up higher and higher, surging in fifteen feet tall and as yet unbreaking. I yelled to Mij as the wave towered darkly toward him, but he went on eating and paid no heed to me. It curled over and broke just before it reached him: all those tons of water just smashed down and obliterated him, enveloping the whole rock behind in a booming tumult of sea. Then as the sea drew back in a long hissing undertow I saw, incredulously, that nothing had changed; there was Mij still lying in the shallow water, still eating his fish.

Whenever I missed Mij from his accustomed haunts I would go first to my waterfall, for there he would spend long hours alone, chasing the one large trout that lived in the big pool below the falls, catching elvers, or playing with some floating object that had been washed down. Sometimes he would set out from the house carrying a ping-pong ball, purposeful and self-engrossed, and he would still be at the waterfall with it an hour later, pulling it underwater and letting it shoot up again, rearing up and pouncing on it, playing his own form of water polo, with a goal at which the human onlooker could but guess. Once, I remember, I went to look for him there and at first could not find him; then my attention was caught by something red in the black water at the edge of the foam, and I saw that Mij was floating on his back, apparently fast asleep, with a bunch of scarlet rowanberries clasped to his chest with one arm. Such bright objects as these he would often pick up on his walks, and carry them with him until some rival attraction supplanted them. I never performed any tests to define his degree of color vision, but whether by chance or selection his preferred playthings were often of a rather garish hue.

Mij had been with me a little over a year when—wandering freely in his Highland range—he was killed by a witless Scot who mistook him, he claimed, for a wild otter. After the worst of my grief, I unsuccessfully sought another otter companion.

After three disappointments, I decided to rear a native otter cub in Scotland, and with that end in view I returned to Camusfeàrna, for a prolonged stay, in the spring of 1959.

I had been there only a week when there occurred a coincidence so extravagant, partaking so insolently of the world of fiction, that had it been unwitnessed or in another land I should hesitate to record it.

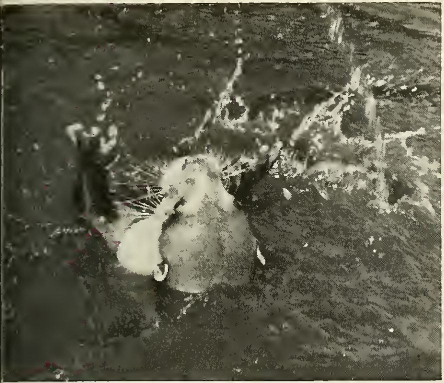
On April 19 I motored to the railway station, thirty-odd miles away, to meet an arriving guest. We returned to a hotel for a "wee dram" before setting off for Camusfeàrna. We sat in the sun lounge that overlooks the sea, but we were well back from the window, and out of sight of the gravel sweep beyond the glass. Suddenly the hall porter came running over.

"Mr. Maxwell!" he called. "Mr. Maxwell! Come quick to the door and tell me what's this strange beast outside—quick!"

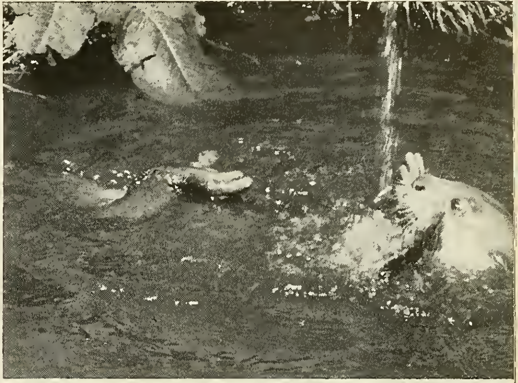
Four people were walking past the hotel, making for a car parked near to the jetty. At their heels lolloped a large, sleek otter, of a species that I had never seen, with a silvery colored head and a snow-white throat and chest. I had a deep feeling of unreality, of struggling in a dream.

I rushed up to the party, and began to jabber, probably quite incoher-

Soaking wet otter invariably emerges from water intent on drying itself on



PINNING AROUND in a horizontal plane while lying on her ack was one of Edal's more energetic aquatic activities.



FEAR OF DEEP WATER probably contributed to Edal's delight in surface play, for most otters prefer to swim underwater.

ntly, about Mij and how he had been illed. and about how time and time gain my efforts to find a successor ad been frustrated at the eleventh our. I must have been talking a great eal, because what they were saying n reply took a long time to sink in, nd when it did the sense of dreaming ncreased almost to the point of verigo. ". . . from Nigeria . . . eight onths old and always been free. ouse-trained, comes and goes as she kes . . . brought her up myself with bottle. In six weeks we've got to go ack to West Africa, so it looked like zoo or nothing—what else could we o? Everyone admires her, but when hey come to the point of actually wning her they all shy off. . . . Poor Edal, it was breaking my heart. . . ."

ny available object. Its "towel" may e a rug, a sofa, or any handy human.

We were sitting on the steps of the hotel by this time, and the otter was nuzzling at the nape of my neck—that well-remembered, poignant touch of hard whiskers and soft face-fur.

Ten days later, Edal became mine, and there was once more an otter at Camusfeàrna, playing in the bourn and sleeping before the hearth.

By far the strangest and most captivating aspect of Edal was that of her forepaws. Unlike Mij, whose forepaws were, despite the dexterity he contrived with them, true paws with wide connecting webs between the digits, hers were virtual monkey hands—unwebbed, devoid of so much as a vestige of nail, and nearly as mobile as a man's. With them she ate, peeled hard-boiled eggs, picked her teeth, arranged her bed, and played for hours with any small object that she could find. She would lie upon her back passing things from hand to hand or, occasionally, to the less adept grip of her webbed but almost nailless hind feet, working always with two or more objects at a time, gazing fixedly at them all the while, as though these extremities of hers were in some way independent of her and to be watched and wondered at. At moments it was clearly frustrating for her to require four feet upon which to walk, for she would retrieve a lost marble by clutching it firmly in one hand—usually the right—and hobbling along on her other three limbs.

She was also an adept, if not entirely imperceptible, pickpocket; with impatiently fumbling fingers she would reach disconcertingly into the trouser pockets of any guest who sat down in the house, hardly waiting for an introduction before scattering the spoils and hurrying away with as much as she could carry. With these curious hands she could throw such playthings as were small enough to be enclosed by her fingers. She had three ways of doing this; the most usual was a quick upward flick of the arm and forepart of the body as she held her clenched fist palm downward, but she would also perform a backward flick that tossed the object over her shoulder to land at her other side, and, on occasion, usually when in a sitting position with her back supported, she would throw overarm.

Like Mij, she was an ardent footballer, and would dribble a ball round the room for half an hour at a time. Here she had an additional accomplishment that Mij never learned, for when she shot the ball wide or overran it she would sweep her broad tail round with a powerful scoop to bring it back within range of her feet.

It came as a shock to me to discover that Edal was the most cautious of swimmers. Even in the wild state, otter cubs have little if any instinct for water, and their dam teaches them to swim—against their better judgment, as it were—for they are afraid to be out of their depth. In the water, Edal preferred to keep her feet either in surreptitious contact with the bottom or within easy reach of it, and nothing, at that time, would tempt her into deep water. Within these self-im-

Clutching gunwale, Edal, *above,* seems to wonder about the advisability of risking a plunge into ocean's depths.

With companion Jimmy, *right,* otter investigates rocks at waterfall in a search for eels that were a mainstay of diet.

posed limits, however, she was capable of a performance that even Mij might have envied; lying on her back she would begin to spin, if that is the correct word, to revolve upon her own axis, to pirouette in the horizontal plane, like a chicken on a spit that has gone mad. In this, as in the novelty of new "aquabatic" powers that she quickly learned, she took a profound delight, and if she had not yet apprehended that otters should swim underwater and only return to the surface for refreshment, she knew all the joys of great disturbance upon it.

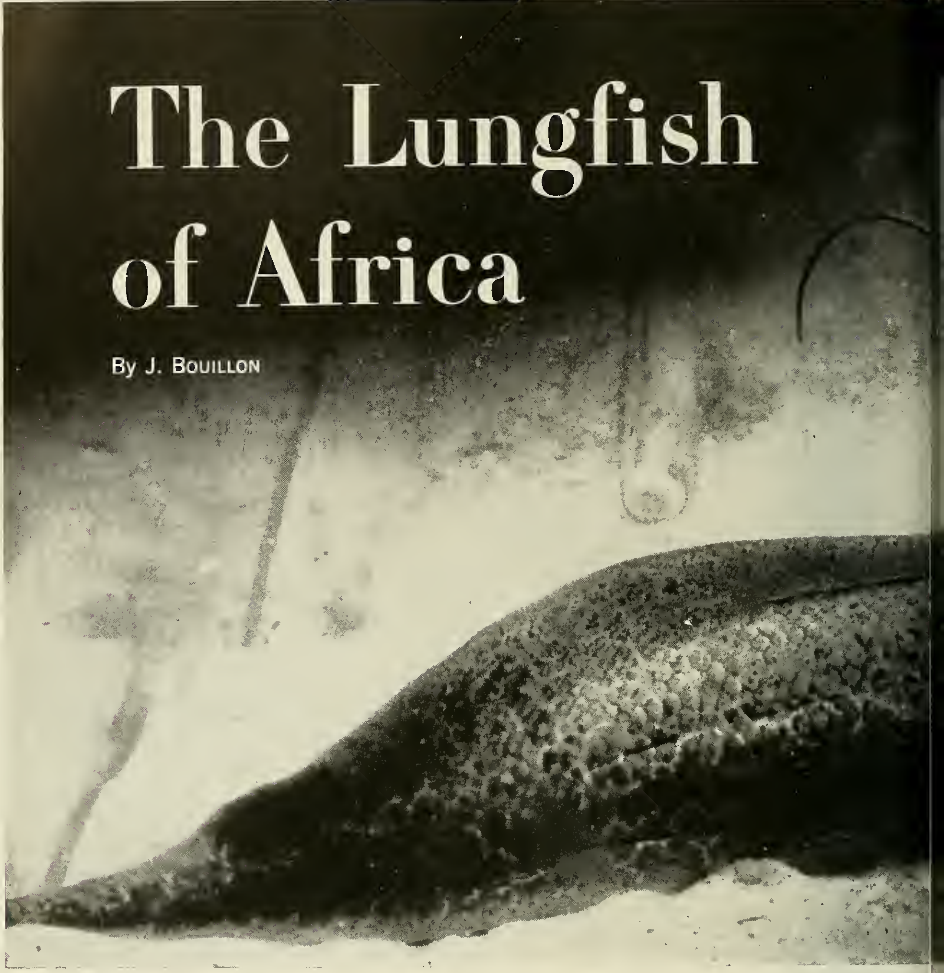
By the end of June, she was swimming as an otter should, diving deep to explore dim rock ledges at the edge of the sea tangle, remaining for as much as two minutes underwater, so that often only a thin track of bubbles from the imprisoned air in her fur gave guide as to her whereabouts. (This trail of bubbles, I have noticed, appears about six feet behind an otter swimming a fathom or so underwater at normal speed; never, as the eye subconsciously expects, directly above the animal.) But though she lost her fear of depth, she seemed insecure in great spaces of water; I think she needed to see on at least one side of her the limits of the element as she swam, and when beyond this visual contact she seemed seized with a *horror vacui,* panicking into frenzied dog paddle as she raced for land.

She gradually gained much confidence, however, both in us and in her proper element, and she gamboled round us in the warm sunshine as we dragged the boat across the sand into a still, blue sea that reflected the sky without so much as a ripple. We rowed for a mile down the coast line, with the glorious ochers and oranges of tide-bared weed as a foreground to the heather, reddening bracken, and the blue distances of mountain heights. All the magic of Camusfeàrna was fixed in that morning; the vivid lightning streak of an otter below water; the long, lifting, blue swell of the sea in the sea tangle; the little rivers of froth and crystal that spilled down from the rocks as waves sucked back and bared them.

Edal, finding herself from time to time swimming above an apparently bottomless abyss, would still panic suddenly. She would turn suddenly for the boat, her small face above furiously striking forefeet, cleaving the surface with a frothing arrow of wave, and leap aboard with her skinload of water. Then she would poise herself on the gunwale, webbed hind feet gripping tightly, head submerged, caught between the attraction of submarine exploration and fear of the deep unknown. Sometimes she would slide, soundlessly and almost without ripple, into deep water, only to panic as soon as she had submerged and strike out again frantically for the boat. Yet in the moments when her confidence had not yet deserted her, when the slim torpedo of her form glided deep below the boat's side, weaving over the white sand between softly waving trees of weed, or darting in sudden, swift pursuit of some prey invisible from above, it seemed as if the clock had been set back and it was Mij who followed the dinghy through these shining waters.

The Lungfish of Africa

By J. Bouillon

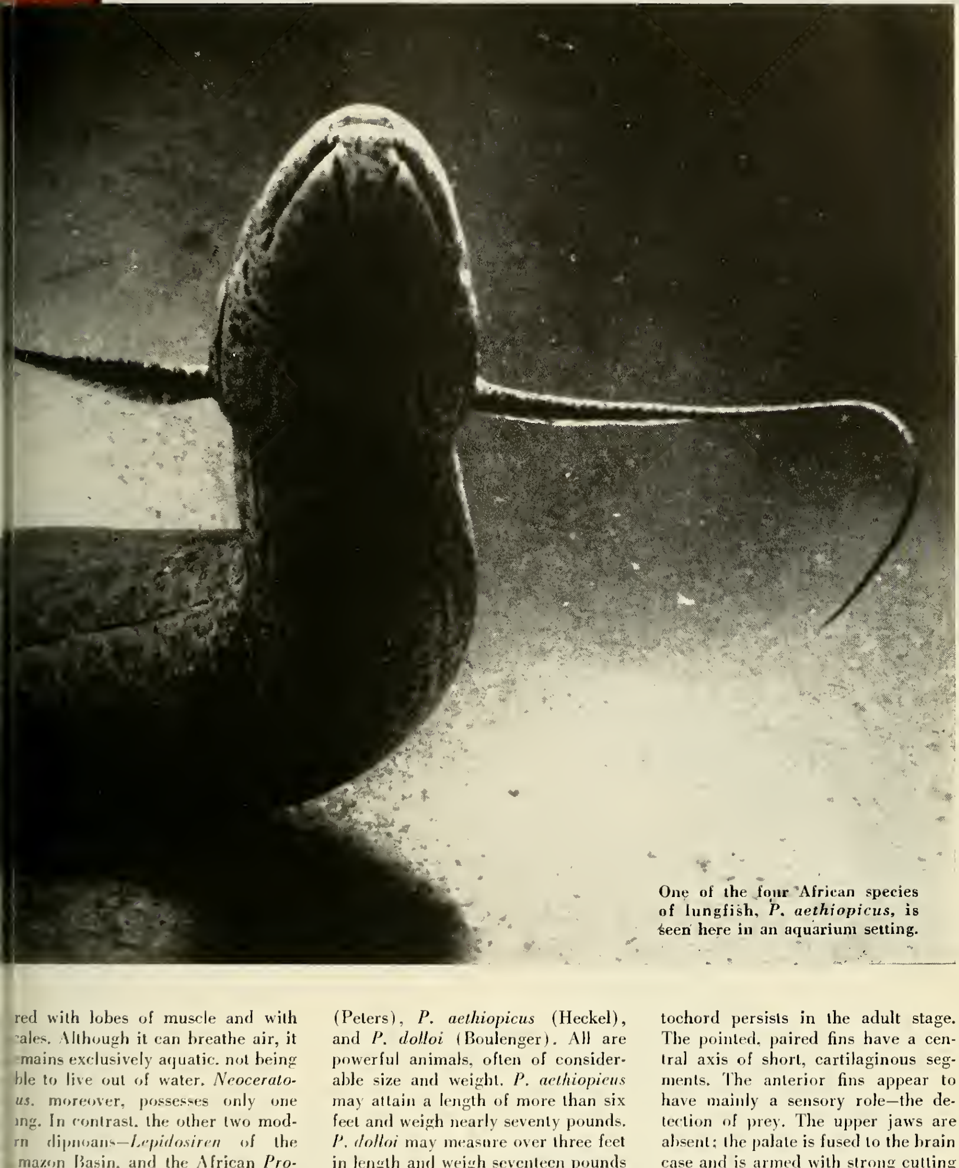


THREE GENERA among the living fishes of the world belong to the group known as the Dipnoi—or lungfish—fossil representatives of which are found as long ago as the Devonian period of the Paleozoic era, nearly four hundred million years ago. The higher bony fishes—as distinct from the jawless fishes, the first (and now extinct) jawed fishes, and the sharks—may be divided into two groups: the ray-fins and the lobe-fins. The ray-fins include such common living fishes as herring and perch. The lobe-fins, however, are represented today only by the coelacanth (*Latimeria*) and the dipnoans.

The three surviving dipnoan representatives are the genus *Neoceratodus*, found in Australia (Queensland); the genus *Lepidosiren*, found in tropical South America (the Amazon Basin); and the genus *Protopterus*, which occupies various African basins. The Order Dipnoi, as the name (dipnein: "double breathing") indicates, have two modes of respiration: through their gills, in the usual manner of fish, and also through their pulmonary sacs, or lungs, (as do certain other fishes)—for they will come to the surface to gulp air, thus filling their lungs. This allows the lungfish to survive not only in oxygen-poor, stagnant water but even in mud, or away from water altogether. Some ray-finned fishes have similar adaptations, but only a few can leave the water even for short periods.

There is almost no essential difference between the latter type respiration and that of the land ve brates. It is not surprising, theref that these animals were long con ered intermediates between the fi and the amphibians. The credit longs to the Belgian paleontologis Dollo for pointing out over half a tury ago that such is *not* the In spite of remarkable convergen Dollo showed that the Dipnoi c not have been the ancestors of the phibians, for both morphological chronological reasons.

Among present-day dipnoans. *ceratodus* of Australia has reta the most archaic features. It is only living representative of the ily Ceratodontidae: as in its ances the skeleton of the paired fins is



One of the four African species of lungfish, *P. aethiopicus*, is seen here in an aquarium setting.

red with lobes of muscle and with ales. Although it can breathe air, it mains exclusively aquatic. not being ble to live out of water. *Neocerato- us*. moreover, possesses only one ng. In contrast. the other two mod- rn dipnoans—*Lepidosiren* of the mazon Basin. and the African *Pro- pterus* (together, they constitute the mily *Lepidosirenidae*)—have the aired fins reduced to tapering fila- ents without scales or rays. The ell-developed lungs occupy almost e whole length of the body cavity.

My own experience with lungfish has been primarily with the Af- ican genus. *Protopterus*. Four spe- ies of this genus exist in Africa: *P. nnectens*, (Owen), *P. amphibius* (Peters), *P. aethiopicus* (Heckel), and *P. dolloi* (Boulenger). All are powerful animals, often of considerable size and weight. *P. aethiopicus* may attain a length of more than six feet and weigh nearly seventy pounds. *P. dolloi* may measure over three feet in length and weigh seventeen pounds or more. *Protopterus* has a long body that ends in a pointed tail: it lives on the bottom, where it moves about like an eel. with long undulations of its body. The head is rather flat; the extremely small eyes are barely visible: the nasal cavities open into the mouth forward of the palate. The superficial bones of the skull are highly reduced. the body is covered with large, thin scales, the internal skeleton is cartilaginous. and the notochord persists in the adult stage. The pointed. paired fins have a central axis of short, cartilaginous segments. The anterior fins appear to have mainly a sensory role—the detection of prey. The upper jaws are absent; the palate is fused to the brain case and is armed with strong cutting teeth. lacking in the lower jaw.

Internally. the uniqueness of *Protopterus* lies in its double pulmonary sacs. the structure of which is nearly identical to that of the lungs of land vertebrates. These highly developed sacs extend back dorsally above the digestive tube and are connected to the throat by a canal. which passes to the right of the esophagus. The gills of *Protopterus* are but slightly developed; only the fourth and fifth arches have functional gill filaments. Gill respiration is thus markedly reduced: however oxygen-rich the water in which the animal lives, it must come to the surface regularly for air. Indeed, metabolic studies show that gill respiration accounts for only two per cent of the lungfish's oxygen consumption. *Protopterus* thus absorbs almost all of its oxygen from the atmosphere. As a concomitant, the circulatory apparatus of *Protopterus* is highly specialized, tending toward convergence with the amphibians.

Protopterus is generally considered omnivorous, feeding on mollusks, crustaceans, small fish, and frogs. In most cases, however, its digestive tube on examination is found to contain almost nothing but vegetable debris—such as herbaceous plants, leaves, fruits, and so forth—mixed with bottom mud. *Protopterus* is too slow-moving to be much of a hunter: it can, however, snap up any prey that passes within reach.

The lungfish is unbelievably unaffected by even the most serious wounds; its metabolism is probably very low, and its sensory faculties poorly developed. It snaps indiscriminately at everything that passes, and sometimes even devours its own tail. The animals devour each other as well, elder eating younger.

PROFESSOR BOUILLON, of the Free University of Brussels Department of Zoology, has studied lungfishes from the evolutionary point of view in both the laboratory and the field.

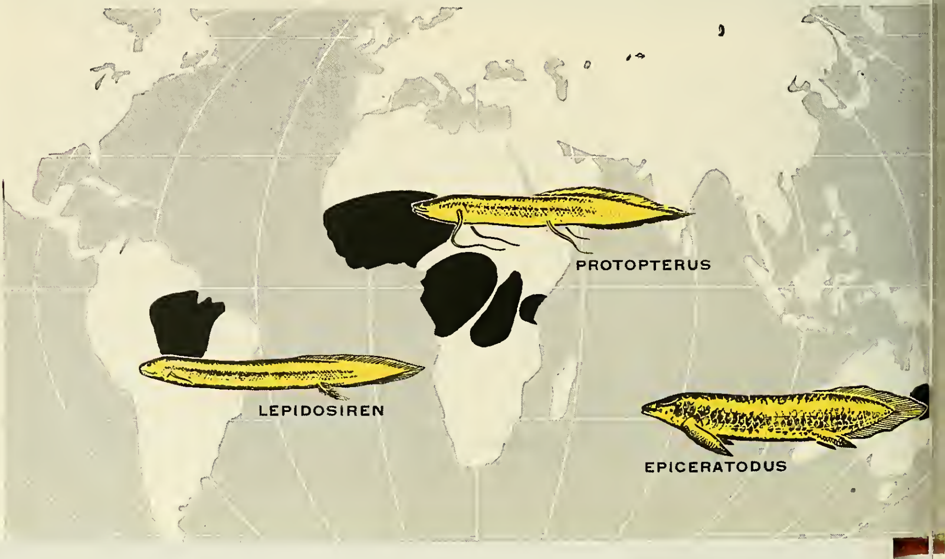
ORIGINAL studies by Brien (1938) and subsequent exhaustive research by Jonnels and Svensson have shown that the life of the species *P. annectens* has two distinctive phases. First, there is a burrowing stage, which begins with the dry season. At this time, the animal falls into a state of torpor inside a "cocoon." Second, at the beginning of the rainy season, the animal enters a nest-building, or reproductive stage. At the beginning of the dry season, *P. annectens* burrows down in the bottom mud, hollowing out a shaft, the depth of which varies from a few inches to well over a foot, depending on the size of the animal. For as long as water still lies above the mud, the lungfish makes periodic ascents up this shaft for air.

As the water disappears and the mud becomes progressively drier and harder, *P. annectens* digs in at the bottom of its shaft and curls up. The skin secretes an abundance of mucus, which dries as the mud hardens and soon forms the close-fitting cocoon. On its upper surface this cocoon has an aperture, connected by a tube of mucus to the animal's mouth. The lungfish now enters the torpid state in which it will remain for the duration of the dry season. In order to breathe, the animal slowly and regularly draws in, through the mucus tube, air that travels down the shaft that the lungfish has previously hollowed out in the surrounding mud.

It is important to emphasize th such a torpid phase is a response the conditions of desiccation in animal's environment. Torpor do *not* take place in the case of fish al to remain in water. In fact, at the ve same time that some torpid lungf in their cocoons are being dug out the mud by the natives—who de them a delicacy—others, in their n mal, active state, are being caught nearby rivers and ponds.

DURING the course of two fi trips to the swamps of the St ley Pool, near Leopoldville, duri 1957 and 1958, Brien, Poll. and author made studies of another Af can species, *P. dolloi*. The inform tion that follows is extracted fr our joint work, published in the *nals* of the Royal Museum of the B gian Congo, *P. dolloi* is found o in the Congo Basin and along coastal rivers of the French Cong swamps are its usual habitat.

In the Stanley Pool, different ty of swamps can be found; those of islands of the Bamu Archipelago a the Djili; the swamps bordering shores of the Pool; and those at mouths of the rivers that empty in it. All of these swamps are grassy wooded, and access to them is v difficult. Although differing in pearance, they have one characte tic in common. Beneath the surf mat of desiccated mud and vegetati in the dry season, lies a layer of ac muddy water, very poor in oxyg



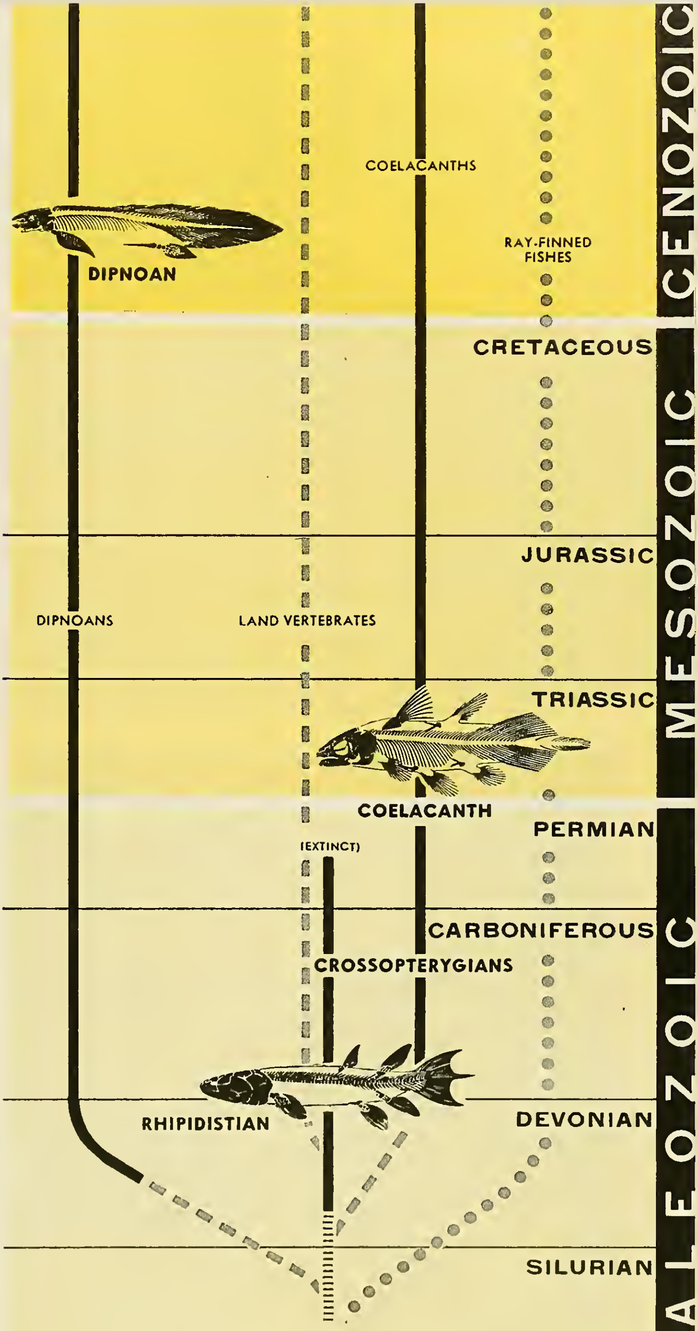
d rich in organic materials and carbon dioxide. This underlying ter zone still communicates with river. however, and at floodtime ter again inundates the swamp.

Most of our observations on *P. dol-* took place in the wooded marshes the shores of the Pool. In such ces. it is difficult to walk on foot, ause of the tangled mass of lianas, nches. and fallen tree trunks that ve been uprooted and shattered by floods of preceding years. These m a landscape that is tortured and aged. but is also impressive and without grandeur. In the rainy son. when the swamps are flooded, can catch both male and female *otopterus*. In July. when the waters ede and the swampy ground slowly erges, muddy and wet, the lungfish appear. burying themselves in the l-soft layer of mud.

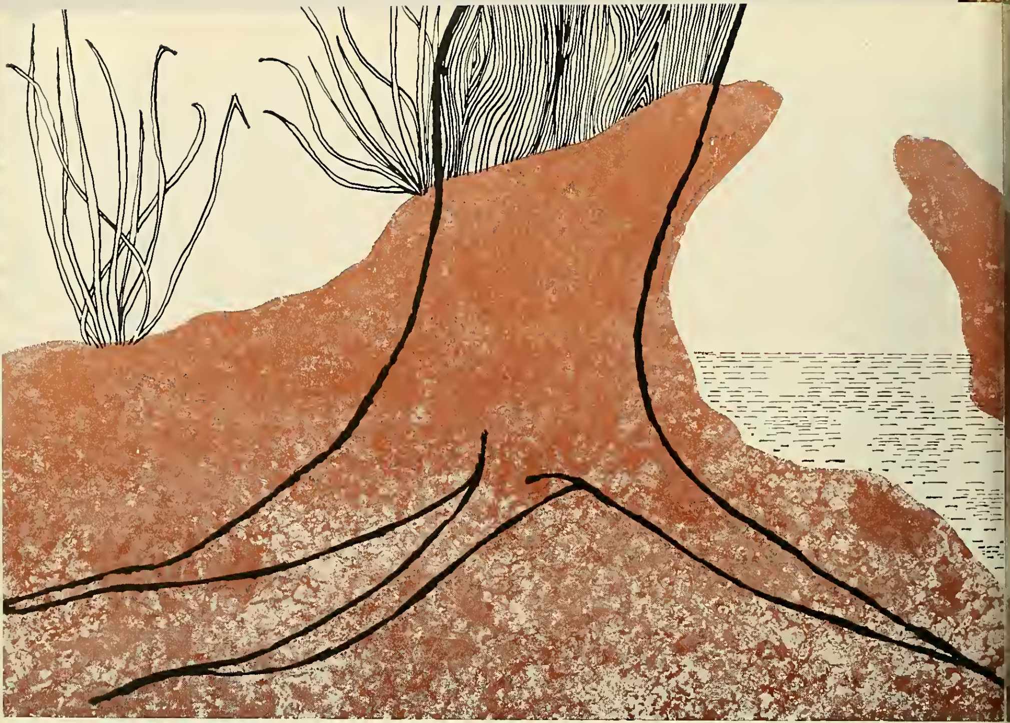
P. dolloi thus behaves as does *P. nectens* when overtaken by the re- ling of the waters. The latter spe- s. as we have seen. hollows out soil it is drying up, and then wraps it- f in a cocoon. In the Stanley Pool amps. by contrast, when *P. dolloi* s down into the bottom mud, it en- nters a more and more liquid e. and finally reaches the subter- nean water table already men- ned. Normally, *P. dolloi* enters ther a cocoon stage nor a state of por. It is only in the event of pro- ged drought that such behavior terns are manifested.

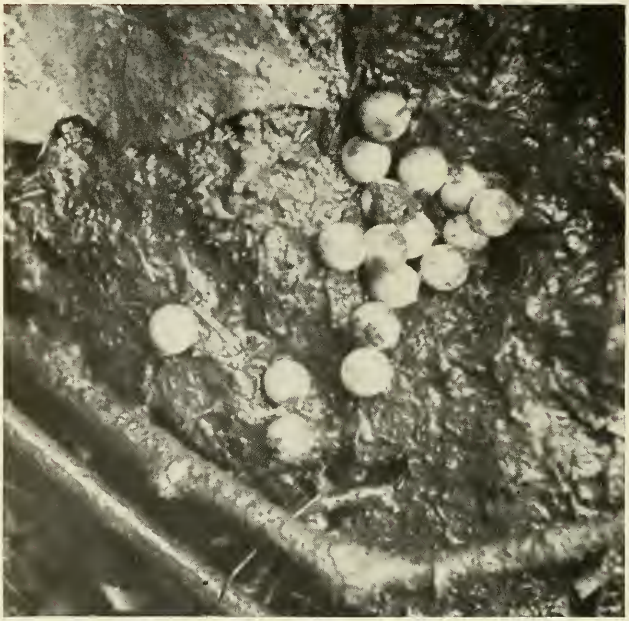
Jonnels and Svensson have care- ly analyzed the movements with ich *P. annectens* digs down into the d. They state that the animal hol- s out its shaft by forcefully gulp- down mud. then ejecting it imme- tely afterward, through the second l openings. Adult lungfish. kept in aria, have been observed swallow- bottom sand mixed with water. l ejecting it immediately after- rd, under force, through their sec- l gill openings—which. as a matter fact. are their largest. They work bottom over in this manner, and ct enormous displacements of d or mud. This, however, is not the thod that *P. dolloi* employs to dig way down into the mud.

Our field experiments showed that *dolloi* buries itself in quite another nner. When placed on top of very mp, soft mud (of the sort that ms the swamp when the flood- ters begin to recede), the animal



A SCHEMATIC PHYLOGENY of the higher bony fishes, *above*, shows the division into two major groups—the ray-fins (dotted line) and the lobe-fins (solid lines). Latter divide into two groups: the dipnoans (lungfish), *left*, and the crossopterygians, *center*. From latter, land vertebrates (dashed line) arose.

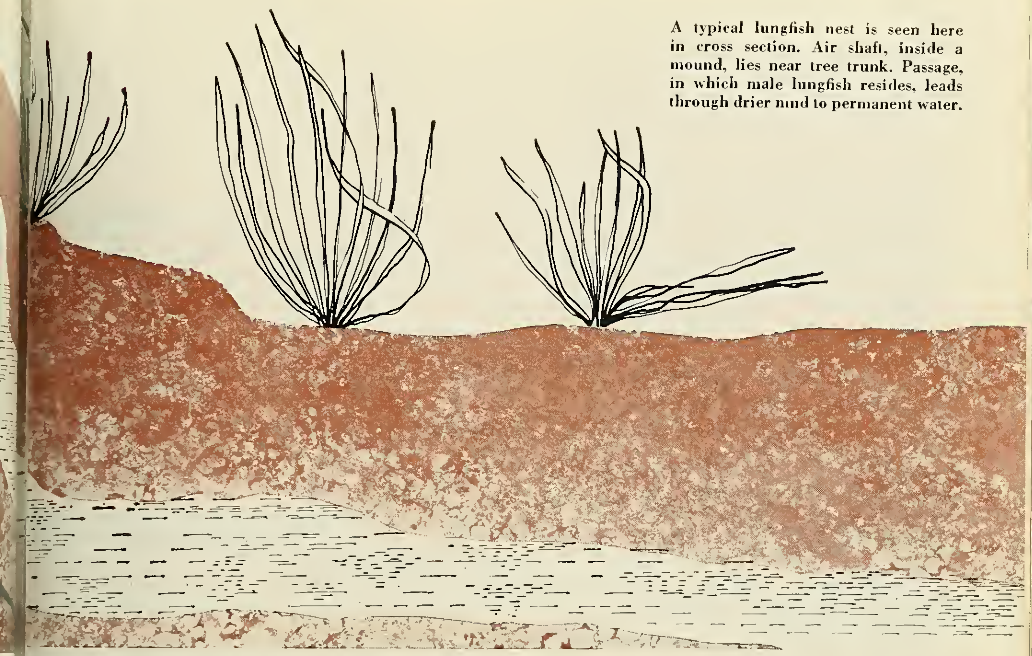




PEA-SIZED EGGS of *Protopterus dolloi* are a yellowish green in color. These specimens were collected from an entry passage like the one sketched above.

immediately plunged in, headfirs burying itself by body-undulatio comparable in speed and charact with those of a large earthworm.

Now, normally, as has just bee pointed out, *P. dolloi* undergoes r dormant period. Though it has witl drawn to the subterranean water the swamp, it nonetheless needs t breathe air at the surface. It can d this only by going back up throug the top layer of swamp mud. Perhap to do this, it utilizes the same hole hollowed out in its descent. But mo probably it opens up a new path access to fresh air. In any case, tl passage used by the lungfish, as emerges from the subterranean lay of water, generally has only a sligl degree of inclination. When it is foot or so from the surface, the pa sage turns upward to form a sma shaft, open to the fresh air. The sha exit may be at ground level or, mo often, at the top of a little mound mud, which resembles a molehill. Tl presence of this mound is clear ev dence that *P. dolloi* digs its chann from bottom to top, forcing the mu outward, mole-fashion. A study of i completed shafts further confirms thi If the mud cap crowning the top



A typical lungfish nest is seen here in cross section. Air shaft, inside a mound, lies near tree trunk. Passage, in which male lungfish resides, leads through drier mud to permanent water.

t mound is removed, the imprint the lungfish's snout is seen in a ucus-lined cavity.

the dry season, the swamps of the Stanley Pool thus show mounds t look much the same as those in dried-up swamps where *P. annec-s* dwells, but their significance is ite different. Those at the Stanley ol do not denote the site of a co-on buried in the hardened earth, t rather the terminus of an air shaft d by the active *P. dolloi* in order breathe air at the surface of the ter. The air shaft and its entry nnel are hollowed out in the most npact areas of the swamp. The minal mound is most frequently ated among the large roots at the t of some tree stump.

These air shafts in the wooded amps of the Stanley Pool—and ubtless in the grassy swamps as ll—are permanent. They are flood-istant, lasting until the next dry son, when the same mounds can ain be seen. The lungfish reoccupy m from year to year, coming back them at the beginning of the dry son. Since the onset of the dry sea- varies from year to year, the date

YOUNG LARVAE, collected from an entry passage later in the season, have now grown to stage of mobility. Note that yolk sacs have been partially resorbed.

SCIENTISTS' HELPERS, who deem lungfish a table delicacy, here stab through the hard surface mud near an air shaft with pikes in order to pierce and immobilize the lurk
male in the adjacent entry channel. Hunt met with succ

of spawning also varies. The fall of water serves as the stimulus that sets off spawning in animals that have reached sexual maturity.

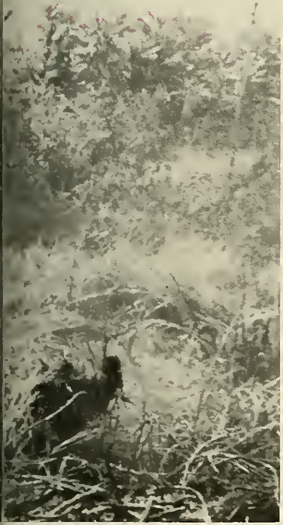
The number of eggs in a *P. dolloi* nest is much smaller than the number for either *P. annectens* or *P. aethiopicus*. Greenwood reports that the number of eggs per nest for *P. aethiopicus* varies from 2.000 to 5.000. He further finds that the ovocytes, ready to be spawned in the ovaries of a sexually mature female, number 2,000. This suggests that several females may lay eggs in a single nest. The nests of *P. dolloi*, however, contain only a few hundred eggs. The ovary of a sexually mature female contains three hundred to four hundred eggs at most. Moreover, while the state of development may vary from one nest to the other, it is homogeneous for each single nest. Thus, it is evident that only one female spawns at each nest.

The spawning of *P. dolloi* takes place in the entrance passage of the air shaft. The eggs are broadcast along the length of the entry channel, to rest on the bottom mud. This distribution of the eggs can be interpreted in two ways: the female may release her eggs gradually as she moves about in the passage leading to the air shaft; or the eggs may all be expelled at once, and the male may then spread them about as he moves back and forth in the channel.

During the whole spawning period, females with empty ovaries are caught in the river or taken by draining the wettest portions of the swamps. It seems likely, therefore, that when the water begins to recede and the mud is still very soft certain mature females are attracted to the swamp by the males, and then into the entry channel of an air shaft. When the spawning is completed, they are then apparently driven away. Occasionally, if the dry season lasts longer than usual, late-spawning females remain imprisoned in the swamp. They survive only by entering a state of torpor until the next inundation.

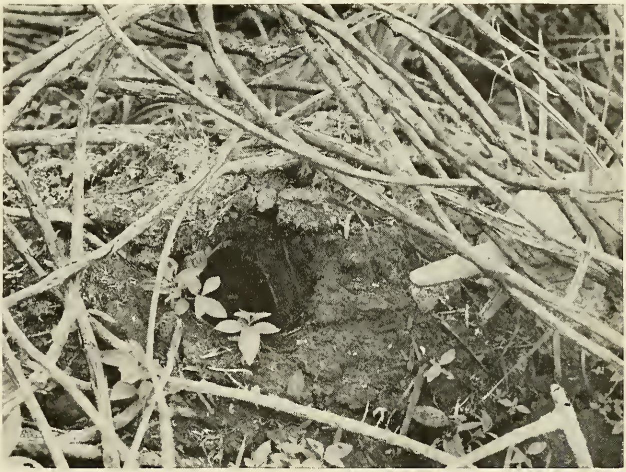
IT is along the entry channel
the eggs develop and the la
are born. When these larvae bec
mobile, however, they congregat
large numbers near the bottom of
air shaft. Only the male remains i
the nest, in the entry channel. He
there passively, inactive during
day at least. He moves about f
time to time, however, by mean
long undulations of the body, con
to the surface of the water at the
shaft to breathe. The movement
the male through the channel agi
the water enough to dissolve trace
oxygen. As the lungfish takes air,
of it is expelled, or allowed to esc
through the gill openings. These
bubbles also contain a little ox
or permit the formation of air poc
in the channel, where the larvae c
to breathe. It is thus probable
the male contributes appreciabl
the respiration of the larvae.

The male may also defend
young against predatory fish, w
inhabit the swamp. It is notewo



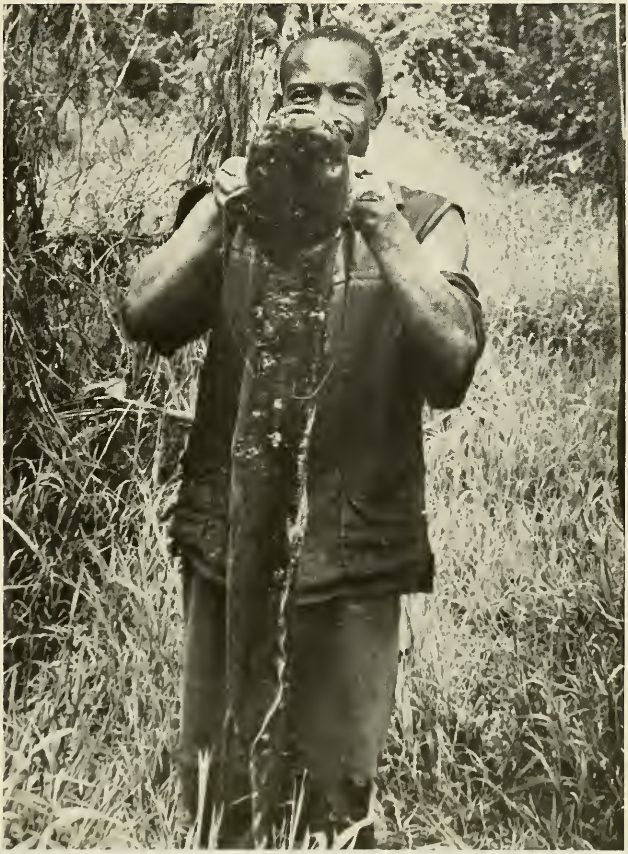
at males collected around the nest
e large in size, while small males
e caught in the rivers and tribu-
ries. It would seem, therefore, that
cavation of the nest and pairing in
uples is the privilege of males that
ve reached a considerable size.

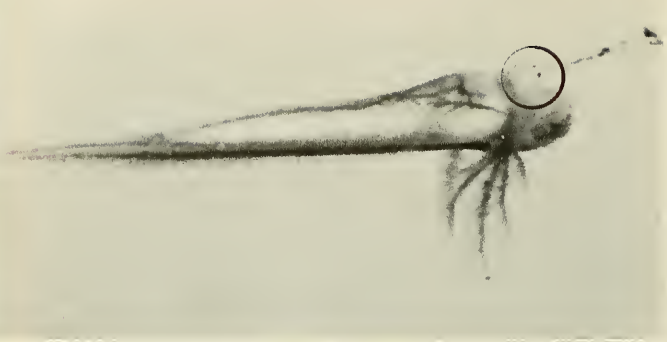
According to native reports, the
ale lungfish is capable of leaving its
uatic redoubt and moving about on
e dry surface of the swamp. Most
thors have repeated this assertion,
it we were not able to verify it. We
d. however, see captured and
ounded males move about relatively
pidly on the ground. propelled by
werful undulations of their bodies.
a moment of inadvertence on the
rt of a fisherman. we saw one of
ese males travel in this fashion to
e hole from which it had been ex-
acted. reach the channel it had in-
bited. and make good its escape. It
thus not impossible, and perhaps it
even probable. that the lungfish
oves about on the mud of the
amp. in the manner of eels. at least



AIR SHAFT MOUND, *above*, is a clue to location of *P. dolloi's* hidden channel.

Helper, *below*, exhibits captured prey, hooked out of channel after stabbing.





Lungfish larva, *above*, is anchored to glass wall of aquarium by its mucus gland *(circle)*. Larva still possesses reduced yolk sac, external branchiae.

during the time when the waters are beginning to recede and the swamp is still completely muddy.

The abundance of palm fruits in the gut of nesting males favors this possibility. The natives report that when the male (whom they take to be the mother and call "mama") is disturbed in his channel, he carries off in his mouth the nestful of young that he is guarding, in order to save them from harm. This was the explanation offered us for nests found suddenly emptied following our first collection of young. No rigorous observation was made that would permit us to confirm the native claim. However, we captured one male at the nest with eggs and hatched young in its mouth and gill cavity; another was caught with its gut stuffed full of larvae. It must therefore be conceded that the male is capable of taking eggs and young in its mouth. But perhaps it does this involuntarily, as is the case with everything it ingests, by breathing in water under force, ready to eject the swallowed objects through the gill openings, as is its habit.

As soon as the larvae can move about, they gather in schools in the channel near the air shaft, for even in this early stage it is urgently necessary for them to come to the surface of the water to breathe. Three modes of respiration thus succeed one another during the period of lungfish larval growth. As the embryo develops, respiration through the outer cell layer is reduced and external gills develop and take over the function of respiration. The lungs, however, are also developing at this stage and soon become the essential organs for the exchange of gases. Later, the internal gills will appear; these are markedly reduced in size. As noted above, aerial respiration is essential to the Dipnoi. Coming regularly to the surface of the shaft to breathe, the larvae will there await the rising of the waters that inundate the swamp and frees them in the rainy season. Having terminated their metamorphosis, during which the external gills disappear, they are able to move about and feed on small organisms living on the surface of the mud or among the roots of grasses and papyrus.

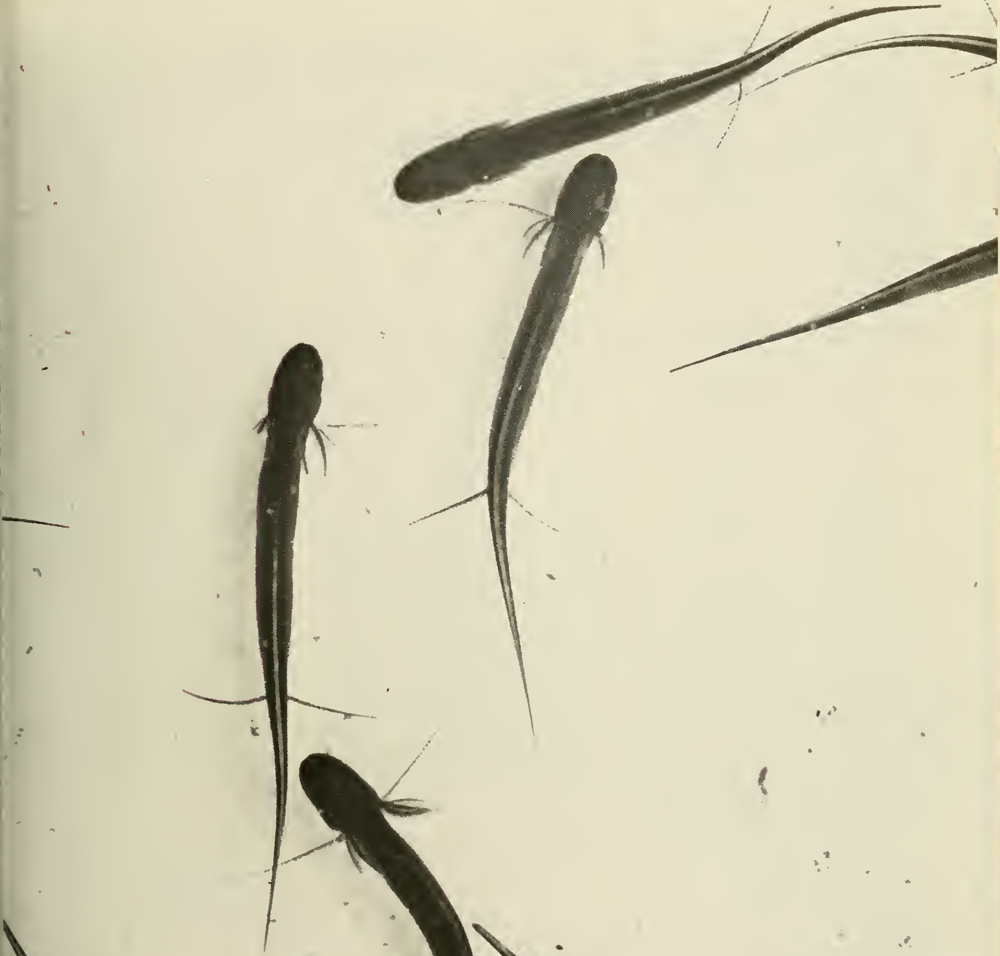
In the swamps of the Stanley Pool, as we have seen, the lowest level remains saturated with underground water that normally extends to the river. After spawning, the females can return to open waters by this route. The males remain near the larvae in the channel, which leads to the air shaft, awaiting the rising of the waters. However, when the dry season is exceptionally early, long, and very severe, males may be trapped in their channels, from which the water progressively disappears.

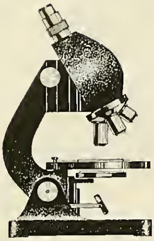
What becomes of these lungfish when they are immobilized in a swamp undergoing pronounced desiccation? Are they capable of entering a state of torpor to await the coming inundation, which will free them? We tested this with an experiment. Two large barrels were filled two-thirds full of very soft mud, with a thin layer of water on the top. Two *P. dolloi*, which had been caught in the river, were placed on top of the mud, one in each barrel. They immediately buried themselves. After two months, the thoroughly dried mud was carefully removed. In each barrel, the lungfish was found to be in state of torpor. When these two spec mens were placed in water, they ir mediately regurgitated large bubbl of gas and, little by little, resume normal activity. From this experimen it may be concluded that *P. dollo* when conditions demand it, may r main buried in a state of torpor. I this state it awaits the next flood w ters that will permit it to resume i normal, aquatic life.

It may therefore be concluded th *P. dolloi* is capable of entering state of torpor when overtaken by t desiccation of the swamps; behavi that is known to be normal in the d season for the other three species this genus. When the water aga rises, the latter three species awake leave their cocoons and enter an a tive phase that includes sexual repr duction. But the fourth—*P. dolloi* the Stanley Pool—buries itself in t mud *not* to enter a state of torpor, b to lead an active life and reprodu there. If it incidentally enters a sta of torpor, this is *after* reproducti and at a time when a long, pr nounced dry season imprisons it.

At the start of this article, it w pointed out that the Dipnoi could n be the ancestors of the land vert brates. If present-day Dipnoi sha numerous similarities in developme and organization with the amphi ans, these similarities are attribut ble, in part, to common ancestr however remote, and in part to co vergent characteristics associated wi a somewhat similar way of life. T dipnoans, as well as those lobe-finn fishes that gave rise to the amphi ians, probably arose from a comm ancestral stock at the beginning of t Devonian period or perhaps son what earlier. These two groups fishes, however, evolved toward t restrial life with unequal success. T swim bladders of ray-finned fish, t pulmonary sacs of Dipnoi, and t lungs of land vertebrates stem from single organ: the pulmonary air bla der of the earliest higher bony fish The remarkable adaptability to e vironment exhibited by the livi Dipnoi enables us to understand h they have survived with relatively tle change until the present peri

Older fry, *right*, exhibit growth feeler-like fins. External gills van when the metamorphosis is complet





NATURE and the MICROSCOPE

Some insect adaptations

By JULIAN D. CORRINGTON

DIRECTIONS for preparing permanently mounted microscope slides of entire insects and such of their parts as antennae, wings, and legs were given in our previous installment [NATURAL HISTORY, May, 1960]. What is the value of work of this nature, aside from mastering the technique of making well-arranged and good-looking mounts? Many readers will find much interest and instruction in forming a collection of slides of antennae or of insect legs; but their interest will rise proportionately as they *do something* with these mounts, after they are dry and ready to inspect.

There is one type of collector who assembles as many of a particular class of objects as possible—be they stamps, coins, shells, or spread butterflies—and who revels in mere numbers, always seeking the new specimen. The serious collector will, however, as his acquisitions grow, begin to study and to classify them. Stamps tell a story of geography, history, biography; natural objects, when arranged systematically, reveal evolutionary sequences and provide marvelous instances of origin and phylogeny, as in rocks and minerals, or of adaptation (the adjustment of the organism to its environment) as in fishes or insect legs. Structural study is fascinating, but is of little value unless it is correlated with observations of the function of the various parts. Let us see how these principles can be applied to the collection and study of a set of slides of insect parts.

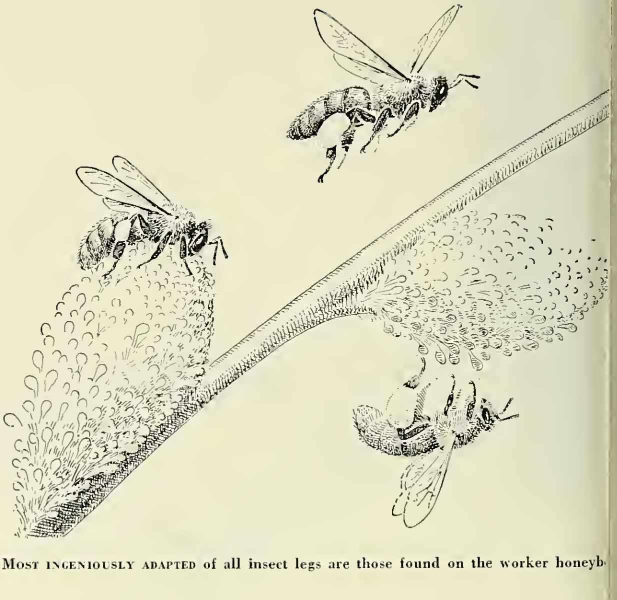
Among members of the great Phylum Arthropoda, the largest by far of all animal groups, the number of antennae provides a major feature in classification. Crustacea, like the crayfish, have two pairs; insects, centipedes, and millipedes have one pair each; spiders and their allies have none. All adult insects have one pair, though they are sometimes minute, as in the flea or dragonfly, or rudimentary in the proturans, where they are termed pseudoculi (false eyes), the first pair of legs functioning as antennae. Known also as feelers or "horns," antennae are movable and segmented appendages of the head that rise from in front of or between the eyes, or from the sides of the face, and fit into sockets. They are primarily tactile organs, bearing hairs and spines that are highly sensitive to touch stimuli. They also include the organs of smell, and often of taste and hearing. Hence, for information about their environment, insects depend to a high degree upon their antennae.

As can be expected in the case of an organ of such importance, the antenna has undergone a remarkable series of evolutionary changes in the different orders of insects. As each order went through a divergent series of mutations of all its structures, the antennal pattern changed by natural selection of that type best suited to the environmental conditions of the particular kind of insect.

Entomologists recognize some thirteen forms of antennae. The *setaceous* or *setiform* (*seta*, bristle) antenna is slender and tapering, each segment slightly smaller in diameter than the one preceding. Look for these in certain species of ground beetles, blister beetles, long-horned beetles, moths, flies, and cicadas. Much commoner is the *filiform* (*filum* thread) antenna, with all the segment of about the same diameter. This type i long and slender, and occurs on man tiger beetles, diving beetles, long-horne beetles, kissing bugs, moths, wasp grasshoppers, crickets, and roaches.

In a modification of the filiform design, each segment is globular in shape so that the antenna resembles a series o beads on a string. This is the *moniliforr* (*monile*, necklace) type, found in man weevils, March flies, darkling beetle and ptinid beetles. The next variation i the *serrate* (*serra*, saw) antenna, o which the lateral surfaces have spines o toothlike extensions, giving a saw-toot effect to the whole appendage. Insect with serrate antennae include some o the click beetles, metallic wood-borin beetles (buprestids), death watch beetles, and some crane flies.

A FURTHER lateral extension of th serrate pattern produced the *pe tinate* (*pecten*, comb) antenna, whic resembles the ordinary hair comb alon the outer surface, or sometimes on bot surfaces (*bipectinate*). Some of th click beetles illustrate this design, whic is also found in goat moths, tiger moth and the males of noctuid, puss, tussoc and some sphinx moths, and in some o the crane flies. Females of the giant sil worm moths, a group that includes thos huge and showy species—the Io, Atla Promethea, Cecropea, Polyphemus, an Luna—known to all collectors, hav bipectinate antennae. The *plumo*



MOST INGENIOUSLY ADAPTED of all insect legs are those found on the worker honeyb pluma, feather) antenna is the final ıtcome of this pectinate trend, the pro- esses being long, fine, and numerous, as ı the males of the giant silkworm ıoths. The *flabellate* (*flabellum*, fan) ıriety is another modification of the ectinate antenna, with very long extensions that together present a fanlike ap- earance. This type occurs in the trepsiptera, an order related to beetles, hich are mainly parasitic in other in- cts, notably in bees. *Whorled* antennae e basically one of the simpler types etiform, filiform, moniliform), but ith whorls of hairs around each seg- ent, as in sand flies and mosquitoes.

A different kind of modification has ıe terminal portion of the antenna en- rged, rather than tapering. If the seg- ents increase in diameter in passing ward the apex, the structure is termed *avate* (*clava*, club), and a large num- er of insects have clubbed antennae, in- ıding many of the Hymenoptera, ater-scavenger beetles, staphylinid bee- es, dermestid beetles, carrion beetles, dybird beetles, some tenebrionid bee- es, some death watch beetles, chryso- elid beetles, bean weevils, butterflies, inch bugs, lace bugs, and ambush bugs.

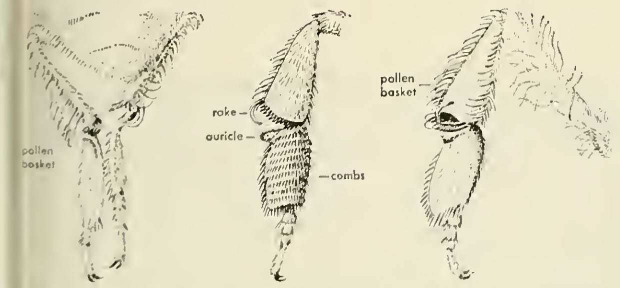
modified clavate design is the *capitate* *aput*, head), in which the enlargement segments occurs abruptly and only at e tip, forming a knob. The skippers, group intermediate between moths and ıtterflies, have capitate antennae with recurved hook at the end of the knob. ıme bark beetles and members of the ısp—bee groups exhibit this type.

A specialization of the capitate form the *lumellate* (*lamella*, layer) anten- , which is so marvelously displayed in e scarabeid or dung beetles. The api- l knob is divided into platelike or aflike segments that can be folded ghtly together or expanded into separ- e leaves. It is interesting to observe ıe of these beetles opening and closing e plates of one of its antennae.

The elbowed or *geniculate* (*genu*, ıee) type, in which the antenna is bent to more or less of a right angle, is characteristic of ants and many other Hymenoptera, of weevils, and other insects. A final form is the *aristate* (*arista*, awn), an elaboration of the capitate antenna. This occurs in the higher Diptera and consists of an enlarged apical segment, which bears a single or a segmented spikelike side piece, the arista. The housefly, with a plumose arista, provides a good example for mounting.

A set of slides of whole mounts of these antennal types provides a series of progressive changes. They start with the simple setiform and filiform feelers, advance through one tendency to lateral projections (serrate, pectinate, flabellate, plumose), or through another trend toward specialization of the apical end (clavate, capitate, lamellate, aristate). The final development is the elbowed or geniculate pattern, which may also be clavate, filiform, or some other type beyond the bend of the elbow. These antennal patterns do not follow any taxonomic sequence that makes them ordinal characters of insects; that is, all Lepidoptera do not have capitate antennae, or all Coleoptera pectinate antennae. Within each of the major orders of insects, antennal evolution has followed its separate pathways. This means that a geniculate antenna in a weevil is not phylogenetically related to a geniculate antenna in an ant, for the weevils are an end line of evolution among beetles, and the ant is an end line among the Hymenoptera. The two forms of geniculate antennae differ in detail while conforming to a generalized pattern. This is a case of *convergence*, wherein structures or habits of diverse heredity in unrelated organisms come to an apparent similarity because of similar environmental requirements.

The mouth parts and wings of insects offer many opportunities for comparative study, but we shall close this chapter on entomology with some remarks about the legs of insects. These are *always* six in number in adult insects—



ACK, INSIDE, AND OUTSIDE views of bee's leg with pollen basket, rake, auricle, and combs.

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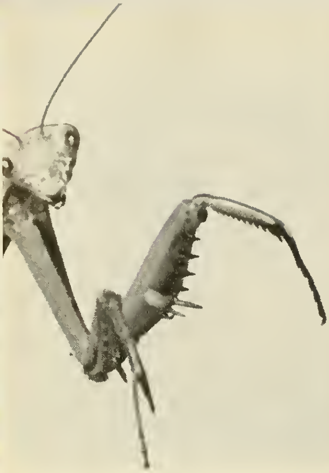
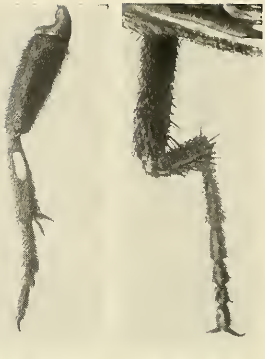




Legs of the praying mantis, *left*, cricket, and housefly demonstrate three adaptations.

three pairs. Hence, one of the synonyms for the Class Insecta is Hexapoda (six legs). For the most part, the legs are similar in all orders, but they display remarkable adaptations for various modes of life. There are five parts of an insect leg: coxa, trochanter, femur, tibia, tarsus. The *coxa* is that chitinous segment that is so set into the body that it acts as a ball-and-socket joint for the whole leg, with the coxa as the ball. The *trochanter* is usually a short segment, but may be elongated in dragonflies and carabid beetles. The first major segment is the *femur*, named from the thigh bone of man. This is the prominent and thick division of the grasshopper leg, containing powerful muscles for leaping. Then comes the *tibia*, generally the longest segment, highly modified for a great variety of uses. It was named from a fancied analogy to the chief bone of the human shank. Lastly, there is the *tarsus* (in man, the ankle), a single segment in primitive insects, but with as many as five divisions in the more highly specialized orders. If the first tarsal segment is much enlarged, as in the honeybee, it is termed the *metatarsus*. One or two *claws* terminate the leg and there may be one or a pair of *pulvilli*—padlike cushions. These are located with or between the claws, allowing the insect to cling to surfaces, and are used, for example, by the fly walking across the ceiling.

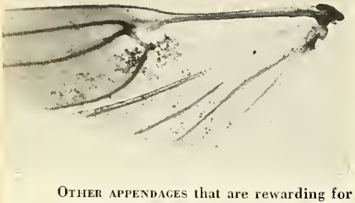
The primary development of the insect leg, as with other great groups of animals, is *ambulatory*, and the construction is correspondingly simple and generalized. All of the five segments are in proper proportion, and none is specialized for other than ordinary duties. Most of the segments are fairly short; those of the wasp are a good example. Elongation of parts results in the running or *cursorial* leg, specialized for speed on the ground, as that of the roach or tiger beetle. The *fossorial* leg is adapted for digging, and the first leg of the mole cricket with its weirdly shovel-like extensions, is the classic example. The *natatorial* leg, such as the third one of the diving beetle, is specialized for swimming—flattened, elongated, and fringed with hairs to make an oar. The *saltatorial* leg, greatly enlarged and extra powerful, is for jumping. The hind legs of the grasshopper or flea are examples. The *scansorial* is the climbing leg. This is exemplified by the third leg of the grasshopper. Its spikes enable this insect to climb up grass stalks in the same manner as the telephone lineman climbs up a pole.

Among non-locomotor specializations of the leg is the *raptorial* type, such as in the foreleg of the praying mantis. Here the femur and tibia are armed with formidable spines, and when these two segments close upon one another the spike are driven through the body of a haples victim and hold it securely while th mantis dines. This fiendish and highl efficient device recalls the Iron Maiden infamous machine of days of the Inquisition. The *stridulatory* leg is a sound producing mechanism. In certain of th Locustidae the hind femur is armed wit a series of minute pegs that are rubbe against the edge of the first pair of wing to set up a vibration with which all of u are familiar. The *scraper* of this musica instrument shows up very well in a slid mount. Another case of special interes to those who make slide preparations i that of the larva or grub of the Horne Passalus, a wood-boring beetle. The cox of the middle leg bears a *file*, a series o very fine ridges, against which the dwar third leg is rubbed as a scraper. This le is so small that until the insect is inspected closely it appears to have bu two pairs of legs.

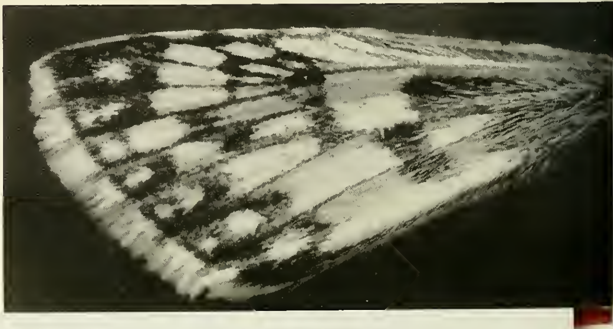
Having examined the structure of number of types of insect legs, the nex step is to watch them in action. Place diving beetle in an aquarium and not how he swims; watch a grasshoppe climb up a stalk of grass in a meadow offer a mantis a fly or small grasshoppe and observe how he uses his forelegs.

Of all insect legs, however, the mos ingeniously adapted for a variety [illegible] formances are the three types [illegible] the worker honeybee. The spectator [illegible] stand close to a bee in the field and se these legs in action, or he may perhap have access to a glass hive, such as ar installed in many schools and museum and penetrate the secrets of the hive a well as those of bee anatomy.

When we put the microscope to wor on the finer details of insect leg construction, we shall find need for some additional terms. *Proximal* indicates nearness to source; a location nearer th center of the body than that of som other structures. Thus, the coxa is th proximal segment of the leg; the me atarsus is the proximal division of th tarsus. *Distal* indicates the opposite location—distant. The tarsus is the dista division of the leg. It should be note



Other appendages that are rewarding for microscopic study are the wings of insects.



these divisions are commonly but rrectly referred to as "joints," reas the true joints, such as those in ian anatomy, are the articulations veen successive segments.

ll bees are clothed with hairs, whose sity, length, stiffness, and structure from place to place. Closely spaced, ranched hairs, which form a tuft over mited area, constitute a *brush;* short, hairs, which all point in one direction and occur in one or more rows, e up a *comb;* long, soft, branched s, generally distributed over the y and on the unspecialized portions he legs, collect pollen.

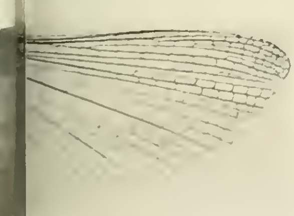
isect legs are borne on the *thorax,* econd body region, of adults (head, ax, and abdomen are the three body ions of an insect). There are three nents of the thorax, designated as pro- (front), meso- (middle), and a- (rear) thorax, and the legs bear esponding specifications. The *pro-acic leg* is somewhat smaller than others. On the front edge of the inner ace of the tibia is a fringe of short, hairs, called the *eye brush,* with ch the bee removes pollen and other ign matter from the compound eyes. s service is especially necessary after bee has plunged to the depth of a er corolla in its search for nectar. metatarsus likewise has modified s, long and bristle-like all round, a cylindrical *pollen brush,* a bottle brush. It is used to p and remove pollen from all the parts of the body. One observer ms that this brush is also used to n the mouth parts.

he most remarkable of foreleg structures is found between the tibia and the atarsus, and is termed the *antenna ner.* A semicircular notch at the inmargin of the proximal end of the atarsus is lined with a row of bristles prising the *antenna comb,* and this apped by a flattened spur, the *velum,* ch arises from the distal end of the a. If an antenna is placed in the h, it can be drawn between notch velum and cleansed of pollen. The ct manipulation must be observed in living bee, or preconceived ideas may out to be incorrect. The velum is movable, but it cannot close over the notch by itself, as it has no muscles of its own; the closure of velum over notch is effected by closure of the leg joint, with the metatarsus flexing on the tibia. It is sometimes said that the antenna is drawn through the cleaner, whereas the opposite motion plays the major role—the flexed leg is drawn along the antenna.

The *mesothoracic leg,* being in the middle, is the least modified of the three. There is a *pollen brush* on the flattened metatarsus, similar to that on the first leg, and it is used to remove pollen from the forelegs and adjacent body parts. Projecting from the distal end, or inner face, of the tiba, in a location corresponding to that of the velum of the first leg, is a *spur,* the most controversial of bee leg structures. Some scientists call it the "pollen spur," and describe it as an organ for digging or prying the pollen balls loose from the baskets (soon to be described) when the bee fills a cell of the comb in the hive. Others have said that the spur supports the wings as they are being cleaned by the nearby pollen brush of the metatarsus. Still others refer to it as a "wax pick," and say the spur removes the plates or scales of wax from the wax pockets on the underside of the abdomen, where this comb-making material is secreted. Possibly all of these observations are correct, and the spur is, in fact, a multipurpose implement that performs each task at a different time.

Largest and most complex of the bee's appendages is the *metathoracic leg.* As on the other legs, this carries a *pollen brush,* located on the outer face of the metatarsus, and used in clearing pollen from the rear portions of the body. In addition, this leg carries a pollen basket, pollen packer, and pollen comb. The *pollen basket* is a most conspicuous and amazing sight when filled, and a deep-well or high-ringed slide may be prepared to show this condition. It takes up most of the outer surface of the tibia, which is not only concave, but also is bordered with incurving, stiffened hairs that assist in supporting the ball of wet and sticky pollen that is carried back to the hive. The basket enables the worker bee to spend more time in the field and make fewer and longer trips than would be the case without a specialized pollen-transporting device. Its Latin name is *corbicula,* or "little basket."

At the distal end of the inner edge of the tibia lies the *pecten,* a comb of short, spinelike hairs, opposite which—at the proximal end of the metatarsus—is a projecting, rounded, smooth lip or plate called the *auricle.* Pecten and auricle constitute the *pollen packer.* Formerly they were termed the "wax pincer" or "wax shears," under the mistaken notion that they removed wax from the wax pockets. Lastly, on the inner surface of



LEFT is wing of squash bug; at center iceroy butterfly; at right, grasshopper.

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the metatarsus lie some ten rows of stiff, distally pointing spines, the *pollen comb.*

Those who find these adaptations interesting may wish to see them for themselves. Slides are easily prepared. Remove the three legs from one side of a freshly killed worker honeybee, and the third leg, from the same side of the body, from a second specimen. Each leg may be placed on a separate slide, but we prefer a composite mount, with all four on a single slide: prothoracic leg, outer surface toward the viewer, at the left; mesothoracic leg, outer surface; metathoracic leg, outer surface, then metathoracic leg, inner surface, the last leg duplicated so that both pollen comb and pollen basket can be seen.

In removing these appendages, be sure to get them complete, including the coxa. Then potash in 10 per cent potassium hydroxide until the legs are a medium golden-brown color, wash them thoroughly in water—preferably a gentle trickle of running water—dehydrate them, clear, and mount them, paying special attention to positioning. When dry, the slide may be studied or photographed. Then, "go to the bee, thou sluggard," and observe closely how she employs these intriguing structures, using a reading glass, if possible.

The bee gradually becomes covered with pollen. She then brushes the grains from the fore parts of the body with the pollen brushes of the first pair of legs and these grains are mixed with others that have been gathered by the mandibles and made sticky with regurgitated honey. This load is now taken by the pollen brushes of the second legs, and finally by the pollen combs of the hind legs, the left comb receiving the contributions from the right side of the body, the right comb serving the left side.

Now the pecten of each metathorac scrapes the pollen from the comb of opposite leg, alternately, and a bit a time. The increments are loosened, tarsus is flexed, and the pollen is pack by the auricle into the lower end of pollen basket. Each addition adheres the preceding mass, causing the ball pollen to grow until it is very large a round. Meanwhile, the bee may also employed in cleaning its eyes, antenn and other parts. At the hive, the wor arches over a cell of the comb and u the spurs to pry the pollen masses lo

THE drone and the queen do not h these pollen-gathering and carry structures. It is curious, therefore, t the size and shape of the greatly larged leg segments are approximat the same in these castes as in the wor bees: the tibia and metatarsus of hind legs in all three castes are lar wide, and flat, but only the worker l the pecten, auricle, comb, and bas All of which points up the biologi definition of a bee. To the poet worker bee is the symbol of industry; the student of government and sociol she is the perfect example of co-ope tion without friction; to the farmer is an important economic asset, prod ing honey and wax of great value; bu the biologist the bee is, par excellen "a bundle of adaptations."

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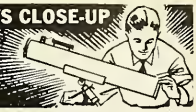

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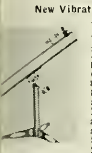

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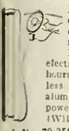

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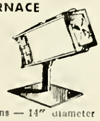

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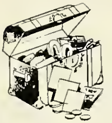

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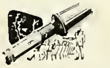

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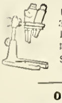

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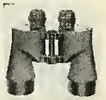

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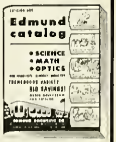

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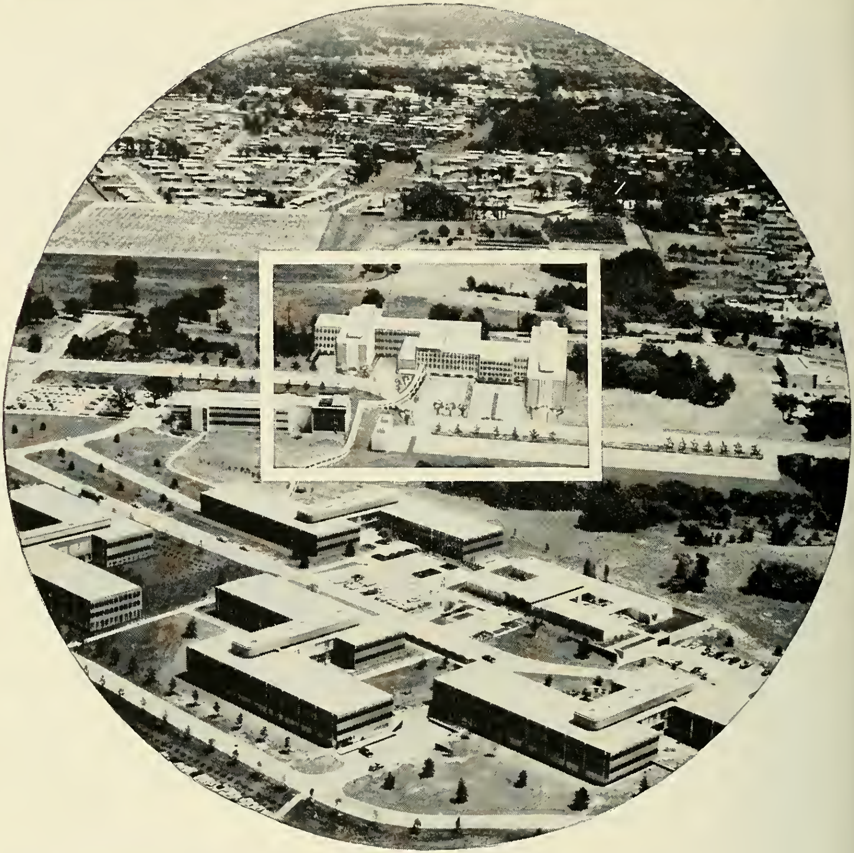

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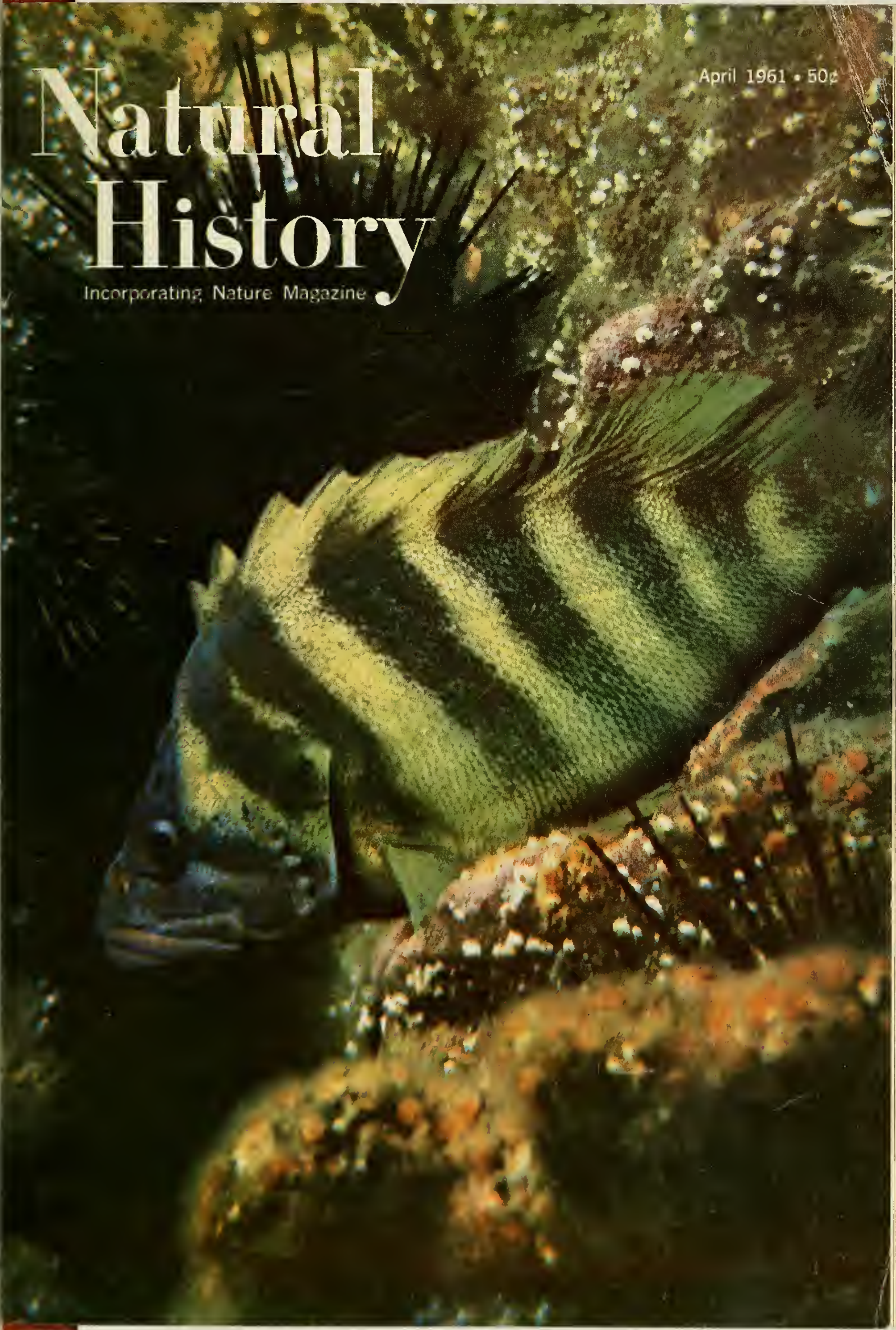

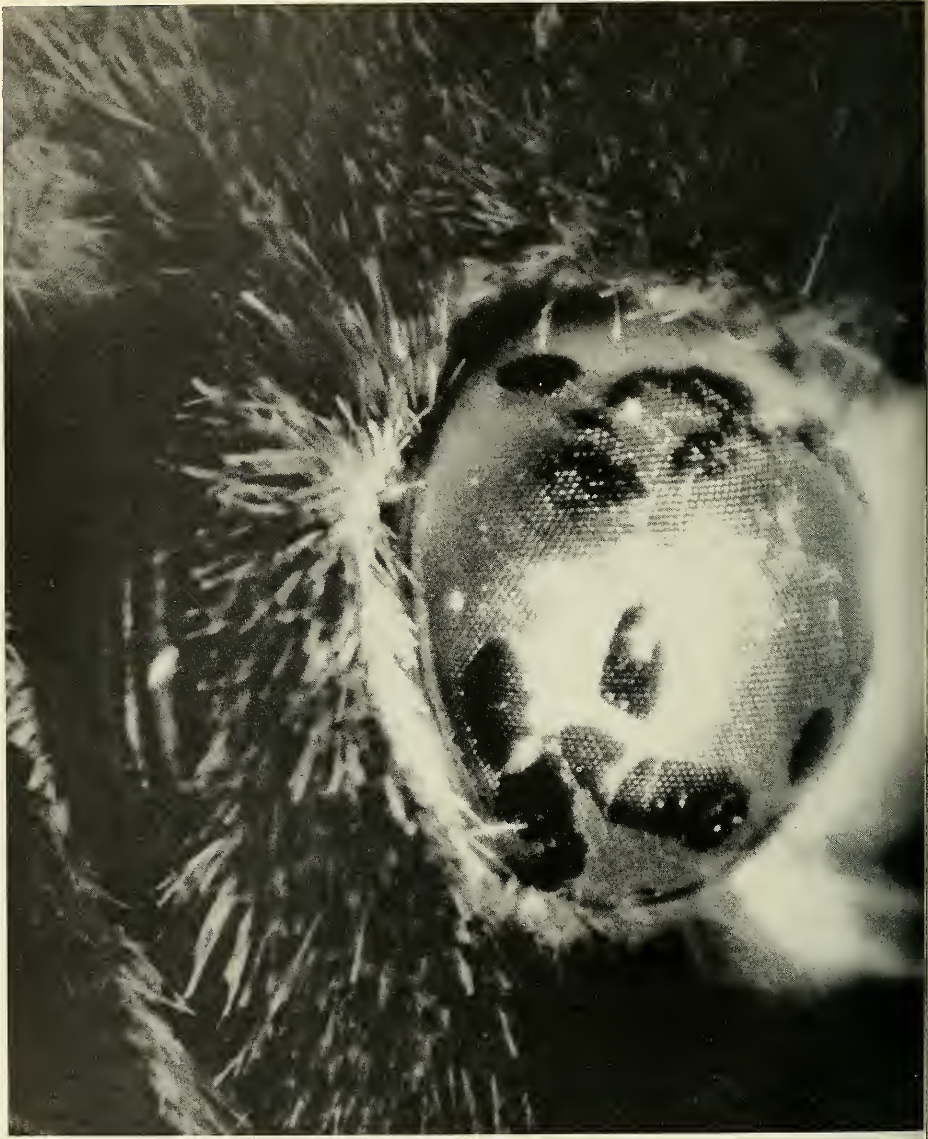

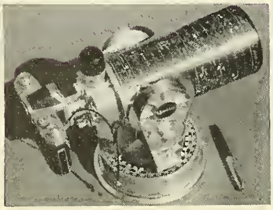

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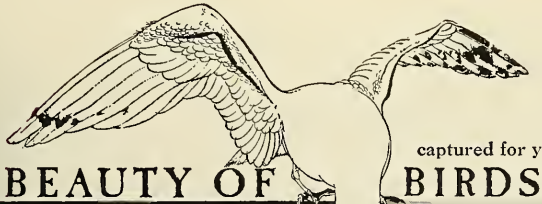

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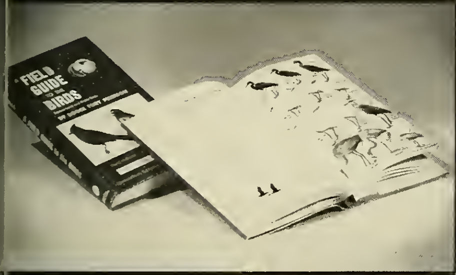

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THE JOURNAL OF THE AMERICAN MUSEUM OF NATURAL HISTO

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COVER: A treefish, *Sebastodes serriceps*, adds color to an underwater scene r Corona del Mar, California. This species of rockfish, as much a part of the r fauna as white barnacles, often nests in calm water near the base of siltst reefs, a locale it shares with sea urchins, with which it is always associated. T photo and other excellent examples of submarine photography were made by Willis E. Pequegnat while studying the life in coastal waters from just below lowest tides to depths of about 150 feet. Named for diving gear used to exp it, this Scuba Zone is examined in Dr. Pequegnat's article, which starts on pag

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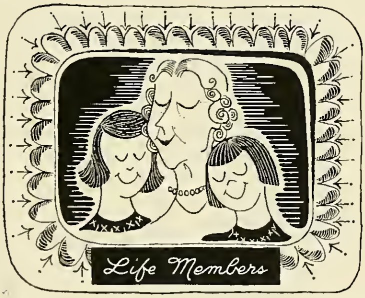
MUSEUM MEMO

NE DAY last January, the American Museum's youngest Life Members—Pamela Golden, age six, and her sister l, age seven—dropped in to say hello. On the following Dr. Winifred Kirkland, one of our oldest Members, by for lunch. The Golden girls have just become Life bers: Dr. Kirkland has been interested in the Museum ell over eighty years—ever since a visit with her par- to our first temporary location in the old Arsenal ding on the east side of Central Park.

ir two youngest Life Members made a charming pic- as they came into the Members' Room, wearing iden- green-figured dirndls, white aprons bordered with gray wool knee socks, and black shoes. They wore dark brown hair in Dutch bobs, sat very straight in chairs, and giggled in un-Life-Memberish fashion. ey said that they go to The Brearley School and are ing reading, writing, phonics, science, rhythm, and work. Pamela said she has made a wooden bed for Christmas doll. She and her may be the only Life Mem- who still play with dolls.

though they have been to the eum only four times. Sibyl and ela have their favorite exhibits. prefer the Hall of North rican Forests and the little live k in the Natural Science Cen- Neither has strong opinions t what they hope the Museum be doing in the future, but if match Dr. Kirkland's attach- to the institution, they will many years ahead in which us know their views.



. Kirkland is petite and snowy-haired, with bright blue that still do not need the aid of glasses. She remembers irst permanent Museum unit when it stood alone off nty-Seventh Street. When the second unit was opened, ecalls, she walked up the stairs (now closed) on either of the Seventy-Seventh Street archway to enter the um, and she wishes she could do it again. For such g-time Member, this doubtless could be arranged. a child, Dr. Kirkland had to empty her pockets of s and other attractive objects before her parents per- d her in the house. She conducted some youthful riments: finding out for herself that milk snakes do ilk cows, that "glass snakes" cannot join their divided again, and that snakes will die before sundown if properly scotched. She wound up with a Ph.D. in anthropology from the University of North Carolina, living with the Havasupai and Hopi Indians as part of her work. In 1949, F. Trubee Davison, then President of the Museum, made Dr. Kirkland a Fellow, in recognition of her work for the Contributors' Program (which raises funds to support the Museum's scientific and educational work).

Dr. Kirkland has noted, for the better part of a century, the Museum's growth in the fields of research, education, and exhibition. She has one fetish about us—that we should save money wherever possible in order to accumulate additional funds for our programs. She suggests, in a twinkling way, that since the Museum gives so much for what it receives, we'd have more money for the things we want to do if we were, perhaps, not so generous.

The Museum, of course, does give much for what it receives. Conversely, the more it receives, the more it is able to give both to its Members and to the general public. We are, at this moment, working to complete the recently opened Hall of the Biology of Man. In the Hall of Indians of the Northwest Coast, we are restoring the murals, cleaning the collection, and improving the lighting. A few of our future plans include a new Hall of Human Behavior, and a Hall of Civilization, and reinstallation of the Hall of North American Birds, and the exhibits concerning the Eastern Woodlands and Plains Indians.

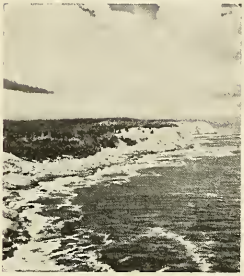
To do all these things, of course, requires money. Present Membership dues make up a valuable and important part of the Museum's operating budget, and we appreciate the support of our entire Membership. But to do what must be done, we must ask for even more—outright gifts, bequests, and an increase in Members' support through enrollment in higher categories.

There are two extremes represented in the respective Life Memberships of the Golden girls and Dr. Kirkland—the first two just beginning what we know will be a long and pleasant association with the Museum; the second continuing her more than four score years of devotion to a scientific ideal. Somewhere in between these two extremes stand almost a hundred thousand Members who can take an even greater part in the present and future work of the American Museum. We ask for your encouragement.

WILLIAM A. BURNS
Membership Chairman

* * * * * * * * * * * *

The
Fortunate Island



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Review

American Seasons: Three Down, One to

By Christopher Ger

Journey into summer. by Edwin Way Teale. *Dodd, Mead, $5.95; 366 pp., illus.*

An archetypical ritual of American culture is packing the family car for a trip. Into the trunk or on the rear deck go the bags and the Coca-Cola cooler, the sunburn cream and the transistor radio, maps, bottle warmers, and all the impedimenta of the well-equipped, part-time nomad. Three times in the last ten years or so Edwin Way Teale and his family have followed this familiar pattern—with a difference. The important baggage that the Teales have carried has been notebooks and field guides, cameras and film and, most important of all, an encyclopedic background of nature lore.

Out of these trips Teale has fashioned three of the most popular nature books of this century—*North With the Spring*, *Autumn Across America* and, most recently, *Journey Into Summer*. The form of each volume is the record of a naturalist's travels in the United States during a single season. But these are no casual Thoreauvian jaunts—no "Week Along the Concord and Merrimac."

The planning and logistics of each highly organized ramble are at once the main strength and one weakness in Teale's approach to nature. He brings to his travels half a lifetime of nature study, the eye of a professional photographer and magnificent staff work. For his intention is not to immerse himself in the experience of summer or autumn or winter; he intends—and to a large measure succeeds—to surround it, overwhelm it, capture it definitively in a hundred notebooks and rolls of film.

The campaigns—the military analogy is inevitable—are carefully conceived, the product of painstaking, intelligent staff work. Unlike the careless, casual traveler, Teale knows that a fog of mayflies will hatch from the mud of Lake Erie between May 17 and June 23, and plans his trip accordingly. He is confident of encountering a dust storm in northern Nebraska in August, and arranges his itinerary to insure the rendezvous. Almost every one of *Journey Into Summer's* thirty-four chapters is built round one or another such confrontation—all three-starred in a naturalist's Bae-
deker and all, perhaps, a little
pointing to a reader for bein
inevitable. The effect is faintly fla
an oversophisticated dinner menu

Read connectedly as a narr
Journey Into Summer, and its pre
sors, suffer badly from this type of
organization. Indeed, they are
close to unreadable. But, by an odd
the same meticulousness and car
distillation of long hours of libra
search, of personal observation an
perience, make all of the vol
extraordinarily effective on quit
other level. Much of the charm o
nature book traces back to two
human delights—the wonder of str
ness and delight in simple diversity
former human taste is what make
bestiary, the traveler's tale, and
fairy story eternal favorites. The
accounts for the continuing fascinat
the catalogue—from Rabelais to
Roebuck, and even the World Alm

As such compendia—as modern
highly scientific successors to the
eval books of wonders—the Teale
are endlessly informative and dive
to the browser. Their value is incr
by the author's determination,
reminiscent of the monkish copyist
annotator, to let no stray fragme
lore or parenthetical bit of bypla
cape him. Thus, in recounting a
visit to the fabulous fossil-be
shales of Florissant, Colorado,
manages to include tabloid biogra
of two eminent entomologists and
to relate the history of the unhappy
man amateur Beringer—systemati
duped by students who progressed
carving him fossil herbs and anim
producing fossil astronomical ob
and finally, after he had publishe
finds, his own name in fossil form

The author also has an enduring
of statistics. Almost every page is
pered with the kind of numerical
that has durable, extrinsic fascin
however trivial its intrinsic import
12,000 osage orange seeds weigh
than a pound (and are food onl

Mr. Gerould, a reporter of scie
for many years, regularly contribu
book reviews to Natural Histo

l and fox squirrels); an elm may a million leaves; Niagara Falls vitably) is over 150 feet high, flows e rate of 200,000 cubic feet a sec- and is lit at night by 20 colored chlights with a combined strength 2 million candlepower. Fireflies, on other hand, never manage to emit than 1/50th candlepower and may s dim as 1/16,000th.

t with all its enticing asides and ium gatherum of facts, the greatest gth of *Journey Into Summer* lies in zen, sharply reported capsule es- . These essays are beaded along the ing 19,000-mile string of the Teales' derings like the shiny stones of a lace. The subject may be anything the history of grasshoppers wind- e to the tops of glaciers—frozen-in, eventually disgorged at the melting of the ice to provide a feast for a generation of birds—to the unex- ned mystery of the birdseye maple strange, mottled grain is charac- tic neither of a species nor a special in, but a growth aberration of indi- al, scattered sugar maples, not re- ed in surrounding trees and often ging during the life of the individ- tree. Again, in a page or two, Teale ches the invasion of the Great Lakes lampreys after the digging of the land Canal bypassing the Niagara r, its disastrous effect on the fishing stry, and the long and ultimately essful search for a method of elimi- ng the eel-like predators.

ONE of the many worlds of nature Teale passes by in his travels is too ll for consideration. He pauses in a sas wheatfield to review the tiny, ning world of the field mice—laid and wasted by the catastrophic tine of harvest. In Oklahoma, he ad- es that drought-proof resident of the bowl, the box turtle—which has n known to jump in order to catch shoppers and, though it hates water, mnly to dunk first one end of its y and then the other in a pool to rid lf of annoying ants. He recalls that tain Lewis, of expedition fame, sured the leap of a prairie jack rab- at twenty-one feet and remarked that years are very flexable, the animal es them with great ease and quick- and can contach and foald them on back or delate them at pleasure." le's own "years" are constantly "de- d" for such pleasant echoes from the t and, like all good travelers, he en- ges his own experience whenever he with the words of those who have eled the road before him.

ndeed, some of the sharpest report- in *Journey Into Summer* is in the d of history. Teale tells again two ries that can never be told often ough: one of the pursuit of the passenger pigeon by market hunters, who sometimes used decoy pigeons with their eyes sewed shut. In half a century, they reduced the species from flights of two billion birds to a single specimen that, dying in a zoo in 1914, brought to completion the extinction of its race. The other tale relates the near-extinction of the bison—an action even more senseless than the killing of the passenger pigeon, since much of the slaughter was done in the name of sport. The British nobleman who moved into the West in the 1850's with a rajah's retinue and, in a single hunt, left 2,500 buffalo carcasses to rot along the banks of the Yellowstone, behaved as Teale says "like a bloodthirsty weasel in a henyard." But perhaps he was little worse than the hide and tongue hunters who left such a trail of bleached bones across the prairie that in later years they could be stacked ten feet high in half-mile piles along the railroads for shipment to eastern fertilizer factories.

Happily not all the stories of men and nature are quite so melancholy. One of the Teales' pleasanter memories is of the amiable symbiosis of tourists and bears around the town garbage dumps of northern Michigan, where bears feed—and tourists watch them—with mutual dignity and respect.

Readers of *North with the Spring* and *Autumn Across America* will have recognized that *Journey Into Summer* is cut to precisely the same pattern—in this case, a recommendation. The itineraries are different and each season has its own wonders, but actually the three books so far published—and the volume on winter yet to come—are a single work, one huge miscellany appropriate to the size and splendid variety of the country it celebrates. Celebration is the proper word, for Teale loves his country in perhaps the deepest way of all, with a passion that embraces rocks, soil, streams and air, and every living inhabitant.

In the face of so much to admire in an undertaking of the scope of Teale's Books of the Seasons, it is perhaps ungrateful to criticize one aspect of the first three volumes that is uniformly unsatisfying. Teale is a nature photographer of the old school, straightforward, and technically more than competent. But his anonymous picture editor is invincibly literal-minded. At their best, the photos his editor selects are pretty or cute: often they miss even this limited distinction. Almost nowhere are they the wonderful, awe-inspiring, beautiful, nostalgic, or simply detailed and informative pictures Teale knows so well how to take. These bland selections—there is always one showing the author, surrounded by nature and hard at work enjoying his surroundings—are in no way worthy of the subjects or the text they purport to illustrate.

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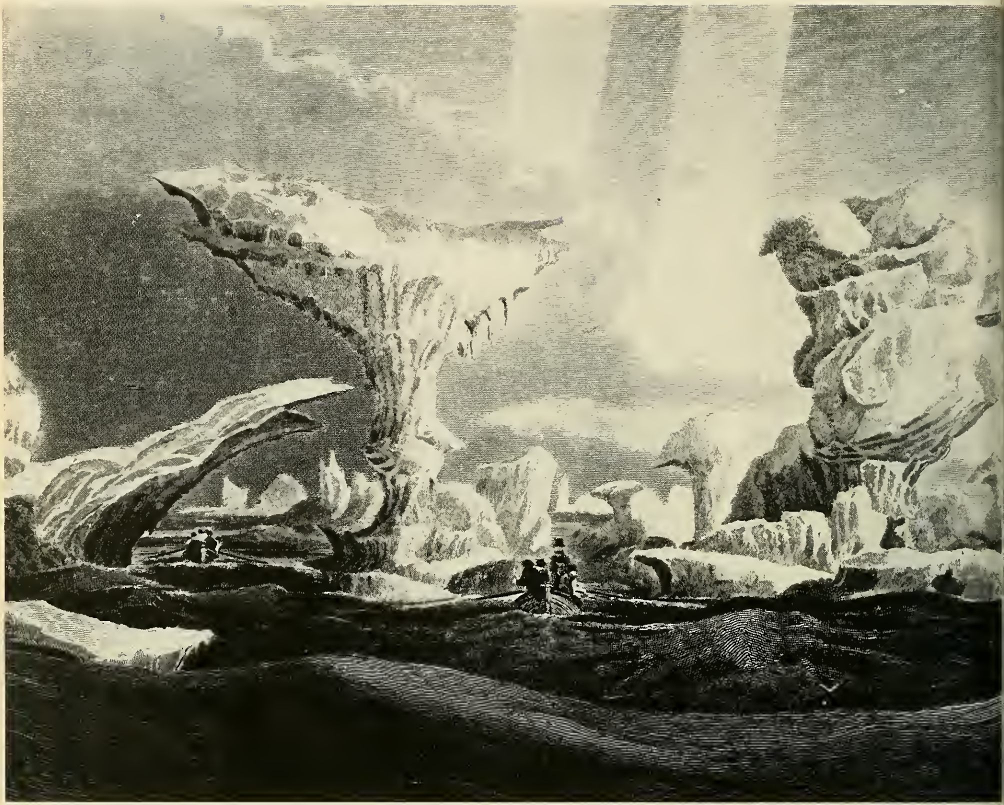

Franklin's 1825 expedition, from *A History of Polar Explor*

IN BRIEF

By John Hay

A History of Polar Exploration, by L. P. Kirwan. *W. W. Norton and Co., $5.95; 374 pp., illus.*

The story of polar exploration is one of trial, tragedy, and success on a major scale over many centuries, from the time of the Vikings to the explorers of the International Geophysical Year. Its history necessarily comprises a wide range of men and nations. The author, who is the Director of the Royal Geographic Society, has managed to assimilate the available material and has used it to write an excellent history book, the first to cover polar exploration in both the Arctic and Antarctic.

The various episodes, which combine to make up the great theme, are concisely presented. Clearly written and often exciting to read, Kirwan's history will doubtless be a definitive work on the subject for some time to come.

A Walk in the Mountains, by Ralph and Molly Izzard. *David McKay Co., $4.95, 253 pp., illus.*

A British foreign correspondent and his wife, Ralph and Molly Izzard, bought three donkeys, took their four children and a Lebanese friend along, and set off on a trip through the wildest parts of Lebanon. Their account of the journey makes very agreeable reading. It is written with modesty and good humor, and at the same time manages to give the reader a sense of the country and the life of its people.

Digging up America, by Frank Hibben. *Hill and Wang, $5.00; 239 pp., illus.*

The general reader's need for a compact account of archeological efforts in the Americas, and the results to date, will be completely filled by *Digging Up America*, written by a professo anthropology at the University of Mexico. To learn more about the A Mayans, the Mound Builders of South and Midwest, Pueblo Indian Eskimos, the reader, if he is so mi will be obliged to go much deeper o own; but *Digging Up America* pro a good introduction to the field.

Spindrift, by John J. Rowlands. *No $3.95; 232 pp., illus.*

Spindrift is an easygoing book of iniscence and description, and also full of the healthy spirits of a who has retired and uses his retire to good purpose. John Rowlands t the tides, gulls, flowers, or ships nea seacoast house in Massachusetts the same alert interest and welcon gives to his small grandson. Rowl is a sensitive and balanced writer w to share his pleasures and excur- s with the reader. The fact that the k was written, as its author admits, random" and "in no particular or- " does not diminish its merits.

: Children of Lilith, by Guy Piaz- . *Dutton, $5.95; 192 pp., illus.*

uy Piazzini was the leader of an ethnographic expedition to Borneo, rested primarily in the Dyaks and r more remote forest neighbors, the ans; societies that are seriously en- gered by the encroachments of civil- ion. His account is a short one and, ranslated from the French, written imes in a somewhat artificial style. reader is greatly tempted to ask for e than he gets in this book, but it s describe two threatened primitive eties with sympathy.

k to the Wilderness, by W. Doug- Burden. *Atlantic–Little, Brown, 0; 251 pp., illus.*

he wilderness world and the wilder- ness life that Douglas Burden writes ut, as an adventuring man who knows reof he speaks, is unfamiliar to most s, for the wilderness is disappearing a great part of the habitable globe. s book records a lifetime of travel hunting in Alaska, Nicaragua, Indo- ia, Mongolia, and the East Indies. Burden is one of those "big game ters" and collectors who does not st about his occupation. "It is a des- ate thing," he writes, "to love wild nals and yet to kill them." His writ- early in the book, especially as it kes his young manhood in the wilds Canada and Alaska, is haunted by the nitive darkness of nature and reveals sensitivity to its beauty.

rdrup's Arctic Adventures, pted by T. C. Fairley. *Longmans, en, $6.00; 305 pp., illus.*

lthough adapted by T. C. Fairley, *Sverdrup's Arctic Adventures* is ically a reissue of the Norwegian ex- er's own work: *New Lund: Four rs in the Arctic Region*. Sverdrup a strong, self-reliant man, an accom- hed navigator, who had his appren- ship in exploration under Fridtjof sen. His continuous voyages and lge journeys in the Canadian Arctic ion between 1898 and 1902 were of t importance in the charting and un- standing of that area. His story— what episodically told, which is con- ent with the many separate expedi- involved—is still fresh and vigorous. rdrup's observations on natural his- are original, humane, and interest- The impression that comes through contemporary reader is one of an fatigable explorer, and a courageous , at the same time, modest man.

The Wonders I See, by John K. Terres, *Lippincott, $5.00; 256 pp., illus.*

For many years editor of *Audubon Magazine*, Mr. Terres here reports the results of his lifetime of detective work in nature, and his enjoyment of his work. The author, who was also in the Soil Conservation Service at one time, is one of those rare human beings who is trained in looking round him and analyzing what he sees. The book is divided by chapter headings into the twelve months and each month's passage brings up many thoughts, observations, and stories in the field of natural history. Can snakes hear? Do gray squirrels find their winter food supplies by memory or sense of smell? Where do birds sleep at night? Did you ever watch the birth of a gall wasp? Have you ever heard the story of the "Great Lapland Longspur Tragedy?" This "naturalist's notebook" is varied and unfailingly interesting.

The White Spider, by Heinrich Herrer, *Dutton; $6.95; 240 pp., illus.*

This book on mountain climbing is unusual not for the writing, which is harsh and inflexible, but for the nature of the subject. The North Face of the Eiger, in the Bernese Alps, is a formidable, sheer wall of icy rock, six thousand feet high, that has claimed many lives. Although it has been climbed successfully it has continued to take its toll over many years, and those who were tempted by it were not infrequently criticized for recklessness. Heinrich Herrer, one of the successful climbers, comes to these mountaineers' rescue with an account of the many attempts made and the terrible risks involved. One supposes there is little room for humor in such an enterprise, but that is just the element we miss most in this stiff, defensive book—not unlike the North Face itself.

Diving for Pleasure and Treasure, by Clay Blair, Jr. *World Publishing Co., $4.95, 348 pp., illus.*

This book's trivial title belies an account of underwater exploration that is of some historical interest. The author and an indefatigable ex-marine, a diver by the name of Bob Marx, were first associated during an inconclusive search for the famous Civil War ironclad ship, the Monitor, and they later joined in an expedition to explore a 200-year-old wreck off Yucatan. They became involved in enough accidents, government incidents, rumors, successes, and failures to attract any boy or frustrated adult adventurer who reads this book. But this is also good reading for anyone with a historical bent, since it culminates in some intriguing research into Spanish and English colonial trade in the New World—all in all, amateur, but fun.

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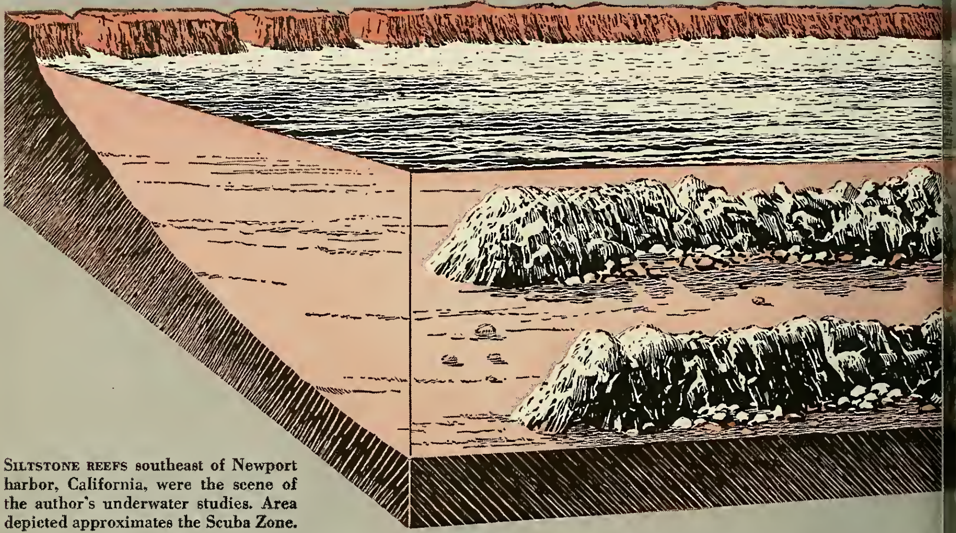
New World for Marin



Siltstone reefs southeast of Newport harbor, California, were the scene of the author's underwater studies. Area depicted approximates the Scuba Zone.

Wherever coastal rocks run into the sea or marine rocks rise in isolation from the ocean bottom to form miniature mountain ranges, one can be sure that many unsuspected marine animals await discovery. It can be predicted that some of these animals will be completely new to science, whereas others will be species that, although well known from other locales, have never been observed in the particular area being studied. I am moved to assert—on the basis of my experience in recent years—that the zoogeographical literature of temperate seas will have to be no little modified as a result of underwater observations by the biologists who have taken to the sea in the uniform of the frogman. I am equally certain that these scientists will broaden our knowledge of the ecology of the shallow, subtidal regions of the world sea.

Using self-contained underwater breathing apparatus—Scuba in short—my colleagues and I have made extensive observations of the various types of marine animals that may be found from the line of the lowest tides to a depth of about thirty meters along the coast of southern California.

During each descent into these shallow waters, we encountered more and more unfamiliar species, especially among the rock-inhabiting faunas. It soon became clear that we were investigating an almost untouched domain of the sea: untouched, not from lack of interest, but simply because of its previous inaccessibility. For years biologists have investigated the life of tide pools or, aboard ships, have scraped and chewed at the ocean bottom with dredges, trawls, and grabs. But they were never able to bring their zones of investigation together—particularly in rock regions, from which dredges and grabs are unable to remove satisfactory samples. Scuba techniques, however, now permit us to close this gap in our knowledge. For this reason I have come to refer to this relatively narrow strip of the ocean bottom—bounded on the shore by a line a little below the lowest tides and on the seaward side by an arbitrary line at a depth of approximatel fifty meters—as the Scuba Zone.

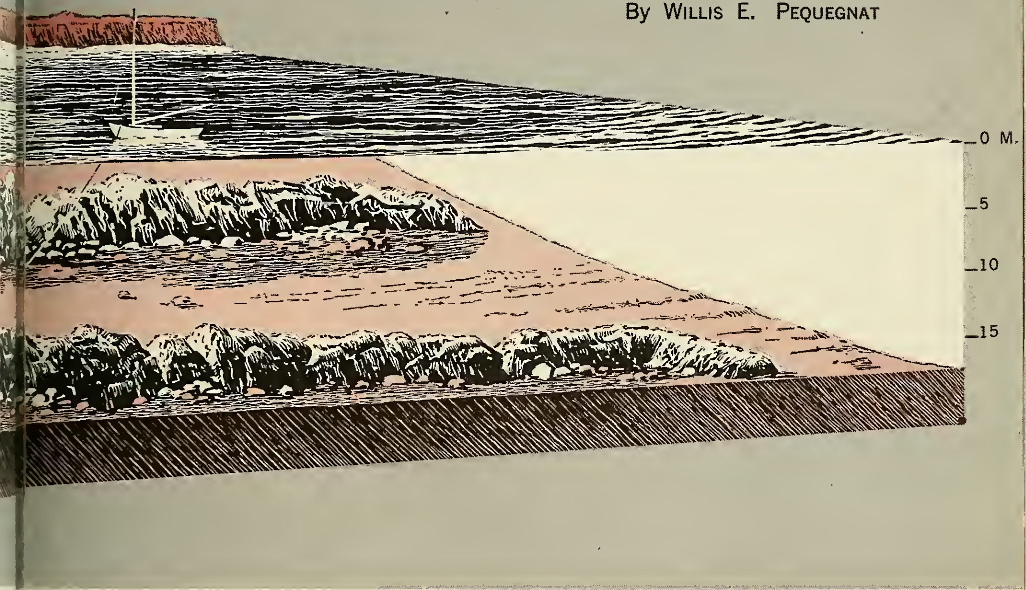
We are all aware that physical factors of the environment, such as temperature and salinity, exert importan influences upon the distribution o marine organisms. But any biologis who undertakes submarine studie will also be impressed by the definit and predictable relationship that exists between the composition of th fauna and the nature of the botton deposit. Communities of organism on rock are remarkably different fron those on soft bottoms. It soon becam evident to us that the rock fauna themselves varied considerably whe the substratum changed from siltstone to sandstone or to basalt, whil the soft bottom faunas changed wit shifts from mud to sand or gravel.

Biological oceanographers subdivide the benthos (bottom-dwelling animals) into two major groups The group with which we shall b most concerned here is known as th epifauna—those animals that live i

Biologists

In shallow, offshore waters lie fertile areas for study

By Willis E. Pequegnat



r upon hard substrata such as rocks r pilings, or even on other organms. The other major group, known s the infauna, is comprised of those nimals that inhabit soft sea bottoms.

The infauna spreads out over early 90 per cent of the world's cean bottoms. The epifauna, howver, is confined largely to the coastal rraces of land masses that, lumped gether, constitute only a scant 10 er cent of the whole benthic region. ecause of this contrast in dwelling pace, one might expect that more pecies would belong to the infauna. uch an expectation is shattered by e fact that there are at least four mes as many epifaunal species as inunal species. This numerical superirity of the epifauna is related in part the far greater number of micronvironments available among rocks han are to be found on monotonous, vel bottoms, which may extend from ole to pole with no more than relaively small changes in such physical onditions as substratum, salinity, oxyen tension, and temperature. Not so with rock outcrops: when these emerge from the bottom and thrust up toward the surface, one may expect to find important gradients in turbulence, oxygen tension, light, and temperature along their walls. All of these factors are capable of exerting adaptive influences upon the epifauna.

One cannot draw a major line of separation between the kinds of animals belonging to the epifauna or to the infauna. Even though clams, snails, annelid worms, and starfish, for example, exist in both groups, we can sharpen the faunal differences by restricting ourselves to lesser categories of classification. Thus, many species and even genera of clams, worms, and the like are restricted to one group or the other. Generally speaking, it is even possible to state that there are more sponges, hydroids, and coral coelenterates, ectoprocts, barnacles, and sea cucumbers in the epifauna, while there are more varieties of clams, sea pens, brachiopods, and pogonophorans in the infauna.

Limitations of space and of species superiority create a degree of population complexity in the epifaunal domain that is unmatched by the infaunal populations. In many instances, not only are the epifaunal species crowded closely together, but the number of individuals of each species is also remarkably large. As a result, individuals of some sessile species form thick crusts upon the submerged rocks. In turn, the labyrinthine channels among the incrustations of these anchored animals provide suitable microenvironments for many sedentary or mobile animals, such as worms, snails, and crabs.

Up to now we have concentrated our attention upon siltstone reefs, which are rather common in the Corona del Mar area. Even with this limitation, we have been overwhelmed by the number of unfamiliar species that were collected. Some of these species have proved to be new to science, and we have already named several of them (*Pacific Science*, April, 1960). Other unfamiliar species proved to be

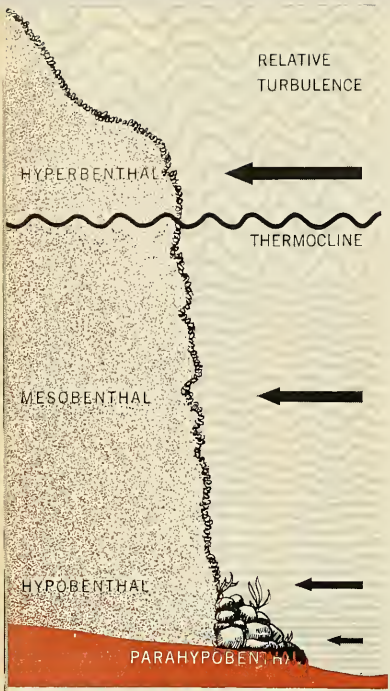


DIAGRAM shows decreasing turbulence of water as one nears bottom of reef.

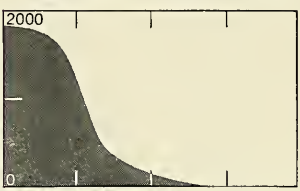
well known tens or hundreds of miles north or south of our area of California, but they had never before been collected at Corona del Mar. Furthermore, we found that many species of animals that had previously been considered rare on the basis of dredging or tide pool studies were, in reality, quite abundant in the Scuba Zone.

THE paucity of literature treating the epifaunas of submarine rock formations served to document the fact that we know really very little about this region of the sea, perhaps even relatively less than we already know about the sea's abyssal depths.

Torsten Gislén's report (1929) on the epifauna of Gullmar Fiord, in Sweden, is the only comprehensive record of diving observations (Gislén used helmet gear) to appear in the century that separates the first observer in the field—Milne-Edwards, who made some underwater studies off Sicily in 1845—from the postwar world. Studies in the 1950's and later, by Drach in France, Riedl in Austria, Kitching in England, and several workers in the United States, are limited in scope. In contrast, the bibliography on the infauna, headed by the papers of C. G. Joh. Petersen of Denmark and extended by Gunnar Thorson, is voluminous. A comparison of Petersen's work with Gislén's will document the greater complexity of the epifauna: Petersen was able to reduce his delineation of the infauna of the Baltic and the adjacent North Atlantic to only nine communities of animals, some of them very limited in range. Gislén found it necessary to describe some forty epifaunal communities in Gullmar Fiord alone.

WE have established a method that we believe gives a fair approximation of the numerical distribution of species on the siltstone reefs we are investigating. Our equipment permits us to remain submerged for at least one hour at most depths in the Scuba Zone. Metal rings, which enclose an area of one-tenth square meter, are fixed against the reef and all the organisms within the perimeter of the rings are removed with hammer and chisel. All materials, which frequently include large chips of rock with burrowing species, are placed immediately into canvas bags and taken to the laboratory. There, the species are identified and all the individuals are counted, measured, sexed, and, in some instances, weighed. Large species—such as gorgonian corals, sea urchins, starfish, and the like—are counted in the field by sampling random parts of the reef with one-meter rings. Occasionally we just count, especially larger fish.

During recent months, under a grant from the Office of Naval Research, we have applied this method to the study of two siltstone reefs situated in the open ocean just southeast of Newport harbor, California (illustration, pages 8-9). The long axes of these reefs run parallel to the shore. The first reef is 200 meters and the second 500 meters offshore: we refer



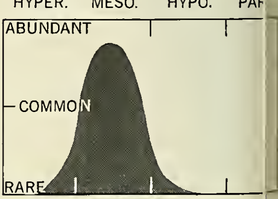
FIXED CLAMS attain maximum density per square meter in hyperbenthal zone.

to them as Reef 200 and Reef 500 spectively. These two were sele for study because of the depth tionships that they possess. Reef rises from a sand bottom at a dep little in excess of ten meters to a lying just two meters below the face. Reef 500 projects upward f a depth of seventeen meters to a p a little less than ten meters below surface. This overlap of depth tween the bottom of Reef 200 and top of Reef 500 has proven to most valuable relationship.

Most of our discussion here wi restricted to Reef 500. About ei meters long and varying from me a few meters to eleven meters width, Reef 500 has a minimal sur area of 1,200 square meters.

Up to now, 330 described speci organisms—*not* including the pr zoans, the more primitive flatwo the nematodes, the annelid worms, the small crustaceans—have been tected on Reef 500. Nor does this include the many species of spor hydroids, and ectoprocts that we been unable to identify. Of this t some 305 are invertebrates, and 2 fishes. In strong contrast to Reef Reef 500 is devoid of large seawe This may account for the absenc abalones on Reef 500 in contras their abundance on the other ree breakdown of the numbers of inv brate species by phyla shows:

	Reef 500	Re 2
Porifero	36	2
Coelenterata	31	2
Platyhelminthes	7	
Nemertea	10	
Sipunculoidea	1	
Ectapracta	28	2
Endapracta	1	
Mollusca	78	9
Annelido	47	5
Arthropada	34	2
Echinadermata	19	2
Chordata	13	1
Totals:	305	31

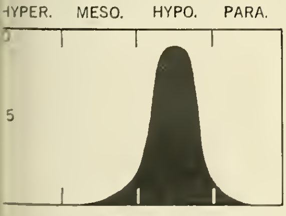


PEAK DENSITY of *Phidilopora pac* is achieved in the mesobenthal re

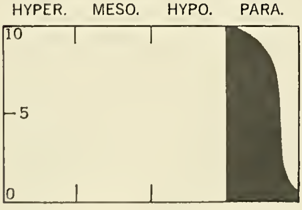
Biologist-assistant wearing a Scuba diving rig uses hammer and chisel to remove a sample from an incrustation of the fixed clams, *Chama pellucida.*

An intelligible portrayal of the re- ionships that exist among this vast ray of invertebrate species and be- een them and the physical environ- ent is difficult to accomplish. The oblem has two facets: first, the ucture of this vast assemblage, ich will include the physical rela- nships among the species and how ey are distributed over the sub- atum; and, second, the functional lationships that exist both among e species and between them and eir physical environment. Here, we all concern ourselves with the first, structural, aspect. Two terms will d us in doing this—the first is the ommunity," a term that the ecolo- st uses to describe any natural semblage of organisms existing gether as a result of common reac- ns to the basic physical characteris- s of their environment. The second the "zone," a term that is often used ther loosely, although it ordinarily nveys the conception of some kind vertical placement—either of or- nisms or of environmental factors. e data obtained from field observa- ns and from laboratory analyses ow us to define a system of vertical nes that reflects the general place- ent of the totality of life on and jacent to these rock reefs.

A most compelling observation—which led to our delineation of ur separate zones—is that a marked adient of reduction in the amount life (the "biomass" of the ecolo- st) occurs from the top to the bot- m of these siltstone reefs. This is to y that, in general, there are more ecies and individuals residing on a it of area at or near the top of a reef an at the mid-point, and more at the id-point than at the bottom. The ree zones of the reef proper were med to reflect this observation: the rms hyperbenthal, mesobenthal, and pobenthal denote the relative numbers of species and/or individuals living on a square meter at the top, the middle, and the lower part of the reef. The parahypobenthal zone was so named to indicate that it existed on the level bottom alongside the hypobenthal region of the reef. It was a temptation at first to attribute the reduction gradient to one of the usual indirect effects of increasing depth (light intensity, temperature), but comparisons of laboratory data between Reefs 200 and 500 proved this conclusion untenable. Reduction gradients were observed on both reefs, but there is a richer fauna at the *top* of Reef 500 than at the *bottom* of Reef 200, even though these two zones lie at the same depth. It appears now that the principal cause of this biological gradient is the change in water movement, which influences the distribution of food around these reefs. This will be discussed more fully in the second part of this article, in the May, 1961, Natural History.

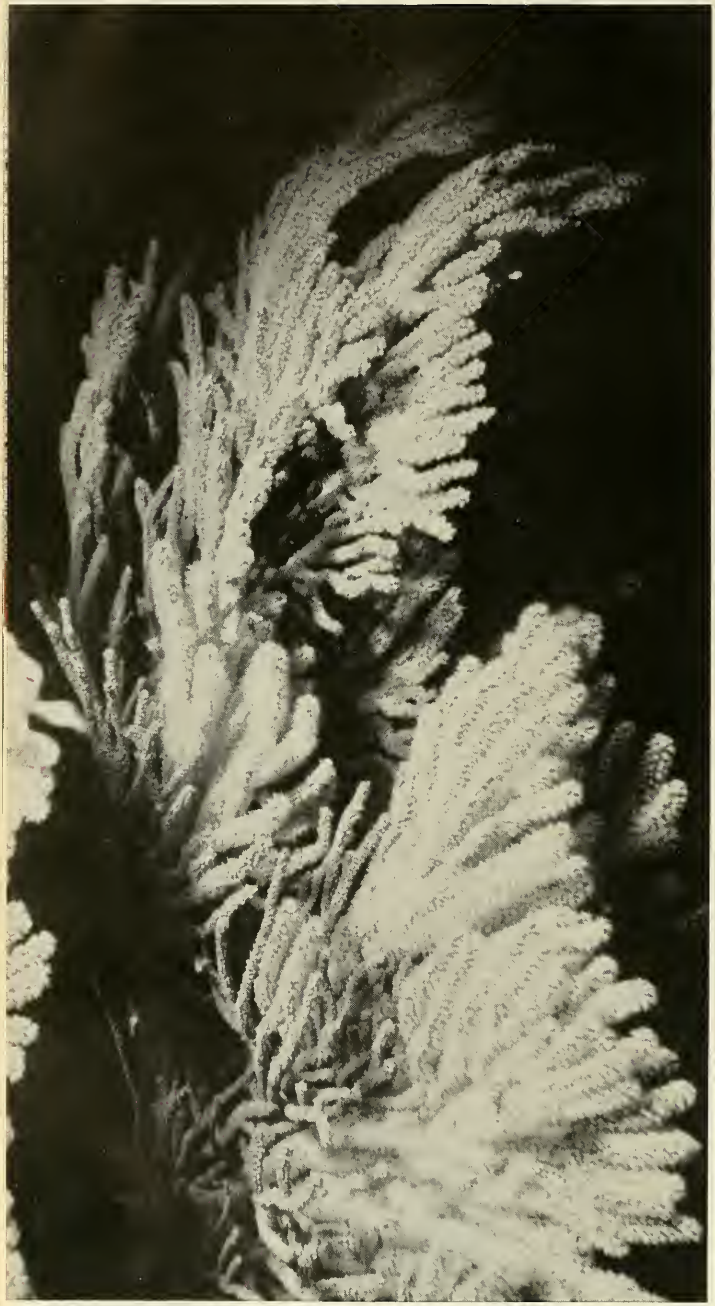


ea cucumber *P. parvimensis* is most umerous through hypobenthal area.



Exclusive to parahypobenthal layer is *B. benedeni*, the burrowing anemone.

Some species are confined to a single zone, but most are not. Yet when a species does occur in more than one zone, it will achieve a peak density (numbers of individuals per unit of area) in a single zone. This can be observed in the frequency curves of a few examples (illustrations, pages 10-11). Thus, an assemblage of species that together reach maximal densities in, say, the hyperbenthal zone, is replaced by another assemblage in the mesobenthal and other zones. Besides changes in density, we found that changes in relative size of individuals occur when a species exists in more than one zone. The same is true of growth form, the niche occupied, and the relative age of individuals: in some mobile species, for example, the young will reach maximal densities



GORGONIAN CORAL sways with surge of water in hyperbenthal zone. Organism, *Muricea californica,* is a suspension feeder, filtering plankton from water.

in microenvironments quite diffe from those occupied by the adult

OUR most shallow region, the perbenthal zone, covers the per reaches of these siltstone reef a cap. On Reef 500, the shallow p of this zone (ten to thirteen met support a thick crust of the fixed c *Chama pellucida.* On Reef 200, a s lar but less solid crust of bivalve lusks, composed of the mussel *My edulis,* occupies the corresponding sition on the reef. Changes in der of these two mollusks that occur variations in depth are striking shown below:

REEF 200	*Mytilus*	*Chama*	REEF 5
Depth in Meters	Av. per Sq. Meter		Depth Meter
2 - 3	10,000	1,800	10 - 1
4 - 5	1,000	300	12 - 1
6 - 7	400	150	14 - 1
8 - 9	0	5	16 - 1
10 - 11	0	0	17 - 1

It is evident that both these moll occur over a considerable ver range, but it is to be noted that 90 cent of the total population will found in the upper three meters. may note also that in the hyper thal zone individual *Chama* ave four centimeters in diameter occur in dense stratifications as m as forty-five centimeters thick. In mesobenthal zone, their diam drops to two centimeters and clumps give way to two-dimensi aggregations. In the hypoben zone, only isolated individuals, centimeter in diameter, are found

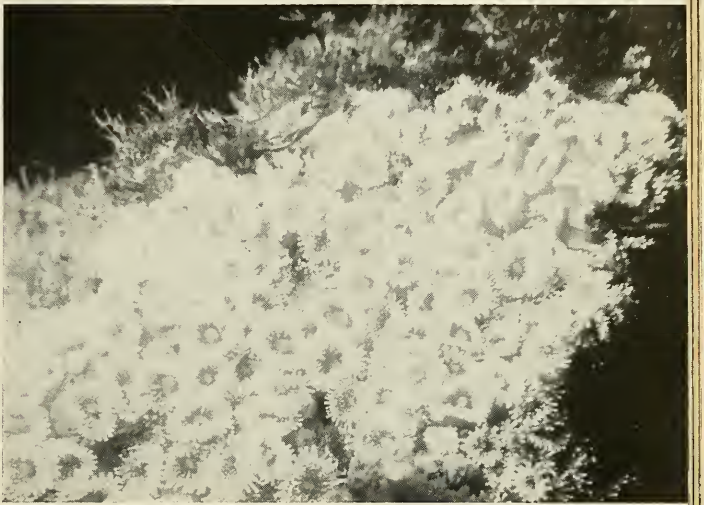
THE inexperienced eye woul unable to discern the presenc these thick *Chama* communities: are often covered by a dense of amorphous sponges, plumed droids, delicate ectoprocts, and sr red algae. Here and there, the sur is dominated by the barnacle *Bal tintinnabulum* (averaging 1,200 i viduals per square meter) or by beautiful, pink anemone-like co terate *Corynactis californica.* In s places, this coelenterate forms nies that attain an average densit 3,400 polyps per square meter.

Adding to the complexity of life the mosaic of color are the bright tacles—usually orange or purpl the large, feather duster worm *E stylia polymorpha,* and of ano

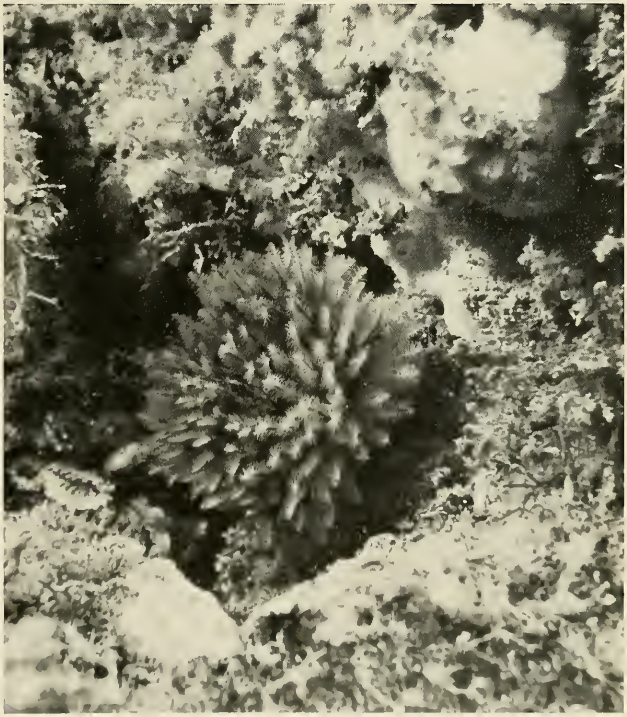
ankton-feeding species, the vermil-
n sea cucumber *Cucumaria lubrica.*
ut these surface manifestations
rely hint at the complexity of this
derwater community. When the
hama stacks are torn apart, one finds
tworms, sipunculid worms, ribbon
rms, the date mussel *Lithophaga,*
d a host of small crabs such as
raxanthias and *Pachycheles.* One
nnot deny the importance of compe-
ion among such a legion of animals,
t there are hints that co-operation
ay have played a role in building up
ch complex communities. The great
nificance of these communities
mprised of numerous species dis-
aying diverse feeding habits is that
e feeding diversity permits a more
mplete use of the varieties of food
ailable at the site.

T other points in the hyperbenthal
zone, especially where turbu-
ice is extreme, the *Chama* commu-
y gives way to the tube mollusk
etes squamigerus or to dense
owths of the magnificent orange
rgonian coral *Muricea californica.*
here the turbulence is too moderate
either of these or for *Chama,* we
d soft mats, five or six centimeters
ck, composed of the amorphous
onge *Lissodendoryx noxiosa,* the
stling clam *Hiatella arctica,* and the
all, feather-like hydroid *Plumu-*
ia setacea. Under optimal condi-
ns, these three species and others
constant associates: the sponge
eates a matrix in which the clams
stle, with only their siphons pro-
ting; the stalks of the *Plumularia*
ow above the matrix surface from
rizontal runners buried in the
onge; a delicate ectoproct like *Fili-*
sia and numerous small, red algae
mplete a miniature forest, through
ich minute worms and crustaceans
culate in a never-ending search for
d and refuge. This community
y cover as much as 60 per cent of a
uare meter, providing a haven for
,000 or more clams and an immense
mber of stalks of the semimicro-
pic hydroid and ectoproct.

F one moves down the side of the
reef to the mesobenthal zone, the
alves give way to distinctly differ-
t types of animals. For the most
rt, the mesobenthal zone is con-
ed to vertical walls at intermediate
pths. Here and there these surfaces
e broken by narrow ledges, vertical



ANEMONE-LIKE *Corynactis californica* is a coelenterate of the hyperbenthal zone. It may form colonies, as shown, averaging 3,400 polyps a square meter.



FEATHER DUSTER WORM, *center,* is in a clump of *Chama pellucida.* The worm, *Eudistylia polymorpha,* has tentacles that are frequently orange or purple.

Zoanthidian *Parazoanthus lucificum* lives on skeleton of a gorgonian coral, *Muricea fruticosa*, in the mesobenthal zone. The zoanthid is bioluminescent.

crevices, and even small grottoes. One becomes aware instantly of a reduction in the water turbulence.

This second zone averages about seventy-five species per plot. So far as growth form is concerned, the compact incrustations of the hyperbenthal zone are replaced by open aggregations of markedly smaller organisms. The most salient external characteristic of this zone of Reef 500 is a luxuriant growth of calcareous ectoprocts. Large areas are dominated by such beautiful species as the pillared colonies of *Diaperoecia californica*. These open thickets of lime provide a haven for small brittle stars, annelid worms of diverse feeding types, miniature hermit crabs, and dwarf snails. These species form a cosmos of their own but, as we shall see later, they depend upon other parts of the reef's ecosystem for their existence. Certainly not all the species of the mesobenthal zone are small.

A very conspicuous component is the zoanthidian coelenterate *Parazoanthus lucificum*, a colonial species that lives upon the skeleton of the gorgonian coral *Muricea fruticosa*. The bright yellow polyps of *Parazoanthus*, which look like miniature sea anemones, are closely packed upon the gorgonian. It is evident that the zoanthid does not await death of the gorgonian before making use of part of its skeleton, but we are not yet certain how it accomplishes the aggression. The discovery of this species at Newport harbor was of special interest: the genus *Parazoanthus* had never before been observed along the entire west coast of the Americas. Furthermore, we found *P. lucificum* to be brilliantly bioluminescent, flashing a bright, blue-white light upon stimulation. This is a trait that had not previously been observed among the zoanthidians. Of considerable interest also is the fact that the gorgonian, *M. fruticosa*, achieves maximal density in the next lower, hypobenthal zone, but the zoanthidian does not attack it at this low level.

Another characteristic species of the mesobenthal zone on Reef 500 is the stony coral *Coenocyathus bowersi*, which belongs to the same order of coelenterates as the reef-building corals of the tropical seas. Even in our relatively cold waters, this species produces massive colonies, of which the greater part are composed of the calcareous cups from which the beautiful, purple polyps arise.

Many of the vertical crevices in this zone support one or more of the giant scallops *Hinnites multirugosa*, cemented to the rock by one valve, its rich orange mantle contributing regally to the spectrum of submerged color. Here we find also the largest dorid nudibranch (a snail without shell) of this region, the orange-and-black *Anisidoris nobilis*, which measures up to thirteen centimeters n length. These large individuals e observed only during the winr months, when they are engaged in taching their yellow ribbons of e in spirals to the reef. Following ts activity, the adults die. When the es hatch, the miniature larvae, comple with coiled shell, swim free in the s- face water where they feed upn plankton, grow, and eventually see back to the bottom. The tiny andy then shell-less nudibranchs contie to grow rapidly until, by late fl, they are ready to begin their rep- ductive cycle all over again.

Even in such a brief list of e mesobenthal zone's species, e is reluctant to omit reference ta small fish—the banded goby *Lythr- nus zebra*, which measures no me than an inch in length as an adult. o secretive that they appear nevero lose contact with the reef, these lie creatures are difficult to see. In brit light, the cherry red of the body c- trasts beautifully with its blue bars. Interestingly enough, another spes of the same genus is found in the ze below, but these two species are vy rarely observed together.

Farther down the vertical wallsf the reef, we pass into the hypobentl zone, the domain of a rather impo- ished fauna, which exists within o meters or so of the bottom. Wr movement is so slight in this regn that we have come to refer to its "the zone of quiet water."

The hypobenthal zone is characr- ized by a reduced number of spes

Another common sight in mesobenl region is the ectoproct *D. californa.*

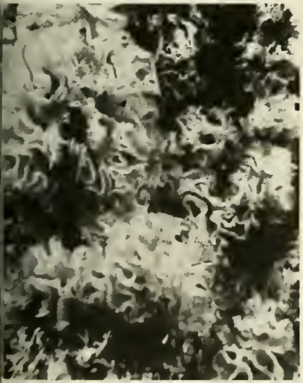
per square meter—averaging about fifty-five—and by a general reduction in the number of individuals. Many rock surfaces are nearly bare, covered only by a thin crust of coralline algae, colonies of small barnacles, or solitary corals. Nonetheless, some species attain their maximal densities in this zone, and some are quite large.

Among these characteristic species of the hypobenthal zone are the solitary coral *Paracyathus stearnsi*, and the related semisolitary *Astrangia lajollensis*. Here, too, we encounter the greatest development of the gorgonian coral *Muricea fruticosa*, the brilliant red sponge *Cyamon neon*, small individuals of the barnacle *Balanus trigonus*, as well as the much larger sea urchins *Strongylocentrotus franciscanus* and *Centrostephanus coronatus*, and the sea cucumber *Parastichopus parvimensis*.

The hypobenthal zone lacks the incrustations that have been considered characteristic of the hyperbenthal and mesobenthal zones. The few bivalves that are found here are either shallow burrowers or types that feed in a manner that rules out crowding; most of the ectoprocts, with the notable exception of the beautifully sculptured and erect *Cellaria mandibulata*, form only thin films over the rock surfaces in the hypobenthal zone.

Although this zone is not as colorful as the others, it does boast one jewel in the form of the tiny goby *Lythrypnus dalli*, whose coral-red body is crossed by a few V-shaped, blue bars. Although formerly considered rare, this species is much more abundant than its mesobenthal relative. Indeed, we must consider it one of the most common fishes of Reef 500: it attains densities of twenty per square meter, especially in October when the tiny young, scarcely more than a quarter of an inch in length, begin to appear in the open. At this time, its total population on the reef probably exceeds 4,000 individuals. Its habit of darting behind the quill-like spines of the sea urchin *Centrostephanus* proves most trying to the photographer in quest of a close-up.

Stony coral, *Coenocyathus bowersi*, is characteristic of mesobenthal layer of Reef 500. Tentacles of polyps are protruding fully from calcareous cups.

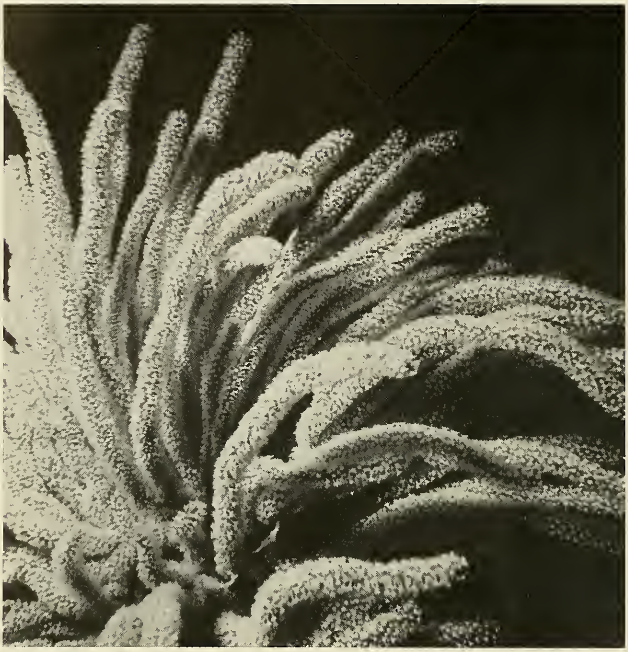


Lime thicket of *Phidilopora pacifica* is lacelike sight in mesobenthal zone.

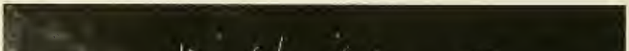
Finally, we may turn to the parahypobenthal zone, which forms a region of transition between the reef base and the level bottom scarcely more than a meter or so in width. We may expect to find here some species that are related to the infauna, others that are doubtless epifaunal (especially when rock debris occurs at the base), and still others unique to this transition area. These species occupy three easily discernible microenvironments: the level bottom itself; the upper surfaces of small rocks; and the area beneath such rocks.

If we limit our discussion to species that are seldom or never found on the reef proper, we can say that typical plots in the parahypobenthal zone support an average of only twenty-five species per square meter. One characteristic species of this zone is the handsome burrowing anemone *Botruanthus benedeni* (whose delicate tentacles look like harmless, tapered tendrils until some food particle brushes by and they whip into action, pulling the morsel to the mouth). The large hermit crab *Paguristhes ulreyi*, which lives in the shell of the snail *Kellettia*, must be included, as must smaller snails—of which *Burchia*, *Conus*, and *Fusinus* are representative. Here, too, we find the small, white sea urchin *Lytechinus anamesus*, which travels in herds that are as voracious in their underwater way as are army ants or locusts on dry land. No organic material that remains immobile will escape these little scavengers as they travel over the ocean floor like miniature tanks. Guided by olfactory receptors around the mouth and on the tube feet, the sea urchins swarm over any carcass and can strip even a large fish to a pile of bones in a few hours.

Other characteristic species of the parahypobenthal zone are the tube-building annelid worms *Diopatra ornata* and *Pectinaria californiensis*. Beneath the surface of the sediments, one will find dense populations of the burrowing sea cucumber *Leptosynapta inhaerens*. The tops of rocks will often support still another gorgonian coral *Lophogorgia chilenis*, whose white polyps stand out in bold relief against the scarlet covering of the skeleton. Beneath the rocks we find aggregations of serpent stars, of



Graceful branches of the gorgonian coral, *M. fruticosa*, achieve maximum density in hypobenthal area. Form is brushier than that of *M. californica.*



Slim tentacles of burrowing anemone, *Botruanthus benedeni*, seem harmless, but they whip food into mouth of this denizen of the parahypobenthal region.

Dr. Willis Pequegnat, a zoologis may rightfully claim total immersio in his subject, the research for whic required mastery of Scuba diving an submarine photography technique He is an Associate Program Directo with the National Science Foundatio

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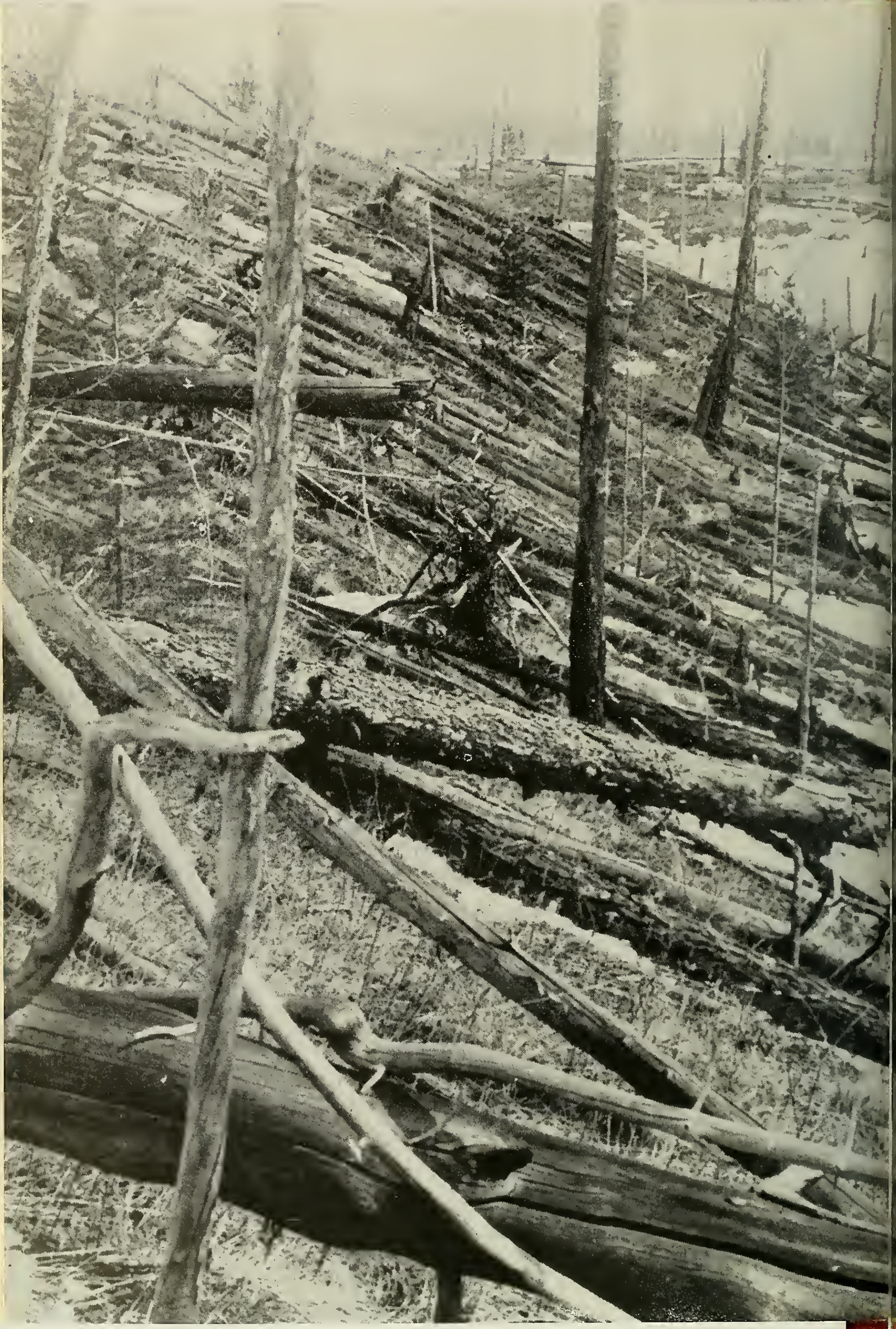
which the largest is *Ophioderma p amensis.* This species, which attai diameter from arm tip to arm tip more than twenty-four centimeters another effective scavenger. The pent stars leave their hiding place dusk to deploy ranks in even spac around the base of the reef, wait for food bits to drop from above.

We have observed that dense gregations of the individual certain species are characteristic the hyperbenthal and, to a lesser tent, of the mesobenthal zones, w they are not found at all in the hy benthal zone. In accord with this, totality of life tends to reduce ma edly as we move from the top to bottom of the reef. And we have served that related species of anin may replace one another in success from top to bottom. We saw, for ample, that one kind of sea cucum reached its peak density in the hyp benthal, but was replaced by other the hypobenthal and parahypob thal zones. Later we shall see t these three species possess remar bly different feeding methods.

These differences in feeding hal may be the key to this and ot patterns of species complementati No single physical or biological fac can account wholly for the distri tion of food, but we are inclined n to stress the importance of curre and turbulence. No matter how fav able all other factors may be at a given place, the availability of food the right kind and in ample sup will be the *sine qua non* of ecolo distribution in a given biophysi complex. The implications of this sertion will be assessed in greater tail next month, when we shall disc food in the sea, how animals adapted to feed upon it, and atter finally to trace the relationship tween the sun and the hordes of a mals we found on our siltstone re

(*To be concluded in May*)

Ferocious grin of moray eel matc its nature. Eels inhabit reef grott



The Unearthly Visitors

Meteorites are samples of outer space

By Brian Mason

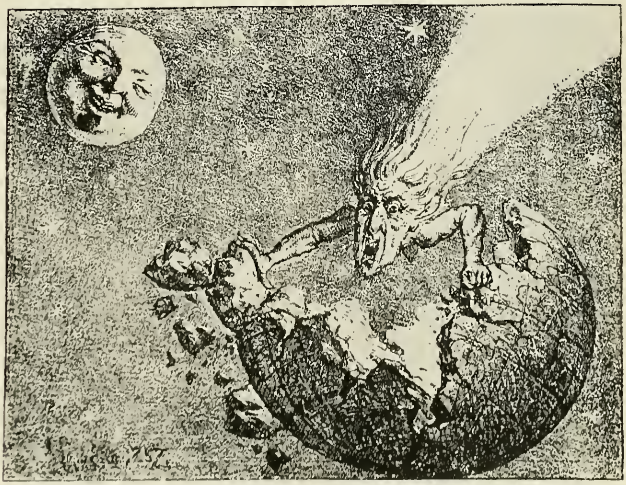
OUTER SPACE is a theme that, in its many variations, affects all of us today. Plans are being made to send manned rocket vehicles to the moon, and ultimately to neighboring planets. The exuberant would extend man's range even farther, to the distant stars. Seekers after adventure now look to interplanetary travel, rather than to our own peaks and poles, as holding the lure of the unknown.

The potpourri of man-made missiles fired into space might be considered a form of terrestrial retaliation, for the earth has been bombarded from outer space since the beginning of time. Fortunately, most of these exotic missiles burn up in the atmosphere and reach the ground as fine dust. However, a larger piece occasionally survives its perilous passage, strikes the earth, and is eventually collected. Such bits and pieces of extraterrestrial matter are known as meteorites. Geologists collect and preserve them as the *only* tangible samples of the great universe around us.

We are fortunate that the frequency of fall is very low. Otherwise, more of us would suffer the rare and undesirable experience of Mrs. Hewlett Hodges of Sylacauga, Alabama, who, on November 30, 1954, was bruised when a meteorite tore through the roof of her house and struck her on what was described as her upper thigh.

There are well-authenticated records of meteorite falls as far back as

FELLED TREES, *left*, litter the area near impact point of Tunguska meteorite.



French cartoon of 1857, *above*, shows purported shock of comet hitting earth.

LARGEST METEORITE on exhibit is the Cape York iron meteorite, weighing 68,085 pounds. It is seen in a photo (*ca.* 1896) as men move it to shore.

LOADING METEORITE on Adm. Robe Peary's ship for Greenland-New Yo

the fifteenth century, but our ancestors were skeptical about reports of stones falling from the sky; and it was not until early in the nineteenth century that scientists were convinced of the fact that objects from space do fall on the earth's surface. In this country, the fall of more than 300 pounds of stones near Weston, Connecticut, at 6:30 A.M. on December 14, 1807, was extensively reported by Professors Silliman and Kingsley of Yale University. However, skepticism was rife. Even the then President, Thomas Jefferson, ventured the opinion that it was easier to believe that Yankee professors would lie than to believe that stones would fall from heaven!

Once it is admitted that falls actually occur, the question naturally arises: what is the frequency of meteorite falls? This is not an easy problem to resolve. In most places, there is no one to observe a fall when it occurs, and the probability of the meteorite's being picked up later depends on many chance factors. A study of the frequency of meteorite falls in densely populated areas shows that the average yearly rate of fall probably lies between 0.3 and 1.0 per million square kilometers. This would mean, for example, between two and eight falls a year in the continental United States.

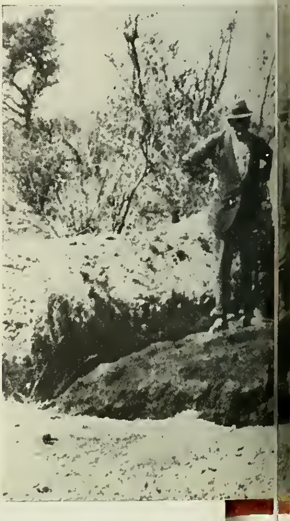
Occasionally, there have been falls of large meteorites that must have forced themselves on the attention of any observer within hundreds of miles of the spot. Such a case was that of the Tunguska meteorite, which struck an uninhabited region of northern Siberia on June 30, 1908. The impact was felt as an earthquake along the Trans-Siberian Railway, five hundred miles to the south, and the forest surrounding the point of impact was felled radially outwards for a distance of forty miles. Meteor Crater in Arizona, 4,000 feet across and 600 feet deep, is evidence of a similar fall of a large meteorite in this country during prehistoric times. Meteorite craters are also known from other parts of the world, generally in deserts, where erosion is very slow and the crater survives. The largest meteorite on exhibit is the Cape York, which weighs thirty-four tons. It was brought back from Greenland by Admiral Peary in 1896, and is now in The American Museum-Hayden Planetarium. The largest *known* meteorite is the Hoba iron, which still lies where it was found, on a farm in Southwest Africa; its weight, by estimation, is probably about seventy tons.

Meteorites are classified into three groups according to their composition: the irons, the stony-irons, and the stones. There is a possible fourth group, the tektites—small, glassy objects that have been found in isolated areas of Australia, Southeast Asia, Czechoslovakia, Texas, and Georgia. They differ from known terrestrial glasses but, since no one has seen one fall, their classification as meteorites is a subject of scientific dispute.

There are about 1,500 well-authenticated meteorites—using the term "meteorite" for a single fall. Each fall, however, may comprise many piece
tens of thousands of fragments ha
been found around Arizona's Mete
Crater, while the Holbrook, Arizon
fall of 1912 was composed of mo
than 14,000 individual stones.

A common misconception has it th
most, if not all, meteorites are iro
It is true that the largest meteo
are all irons and that, in museu
lections, irons generally domi
stones. However, if we exa
statistics of *finds* (meteorites
but *not* seen to fall), as opposed t
(those collected after having been se
to fall), we see a remarkable revers

HOBA IRON meteorite, seen in vinta
photograph, is largest known, weighi



oyage was photographed by Peary, ho also took the preceding photo.

Journey's end comes for meteorite as workmen roll it down ramp to resting place at The American Museum, where it is displayed in Hayden Planetarium.

THOS McLARNON
W 50 ST

n the proportion of different types etween the finds and the falls. The eason is not far to seek: The relative bundance of irons as finds is due to heir being easily recognized as mete- rites. However, a stony meteorite—un- ss seen to fall—could easily be over- oked. When we plot the finds of orites in the United States on a we might conclude that the Great have been bombarded by a hos- aven, while New England has mysteriously spared. The reason at *any* stone on the Great Plains likely to attract attention, whereas the rocky terrain of New England it is a very unusual stone indeed that receives a second glance. Thus we get a truer indication of the relative abundance of different types of meteorites from the relative proportions of those actually seen to fall. These figures show that the stones are far more abundant than the two other types of meteorites taken together.

stimated seventy tons. It is still in lace where found, on a farm in Africa.

Iron meteorites consist essentially of iron-nickel alloy—the average composition being about 91 per cent iron, 8.5 per cent nickel, and 0.5 per cent cobalt. All meteoritic iron contains nickel, and a test for this metal is useful for eliminating specimens of cast iron and similar material, which are sometimes mistaken for meteorites. The irons commonly contain small, rounded inclusions of troilite (iron sulphide) and schreibersite (iron-nickel phosphide). The metal generally shows a definite structure—known as Widmanstätten figures—that may be brought out by etching a polished surface with acid. The Widmanstätten structure is a network of bands, crossing one another in two, three, or four directions: the bands are composed of kamacite (a nickel-iron alloy with about 6 per cent of nickel) bordered by thin layers of the nickel-rich alloy taenite. The angular interstices of the network are filled with a fine-grained mixture of both kamacite and taenite, which is named plessite.

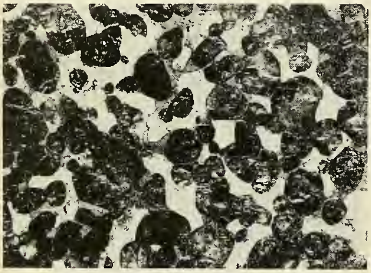
This distinctive structure is the result of a chemical segregation after the metal crystallized. Originally the nickel-iron must have been molten, and then have solidified as large crystals of a homogeneous nickel-iron solid solution. However, on further cooling, this solid solution was no longer stable; it broke down into a mixture of two phases—a nickel-poor one (kamacite), and a nickel-rich one (taenite). The regular arrangement of the bands results from their being oriented parallel to the octahedral planes in the original homogeneous nickel-iron crystal. Such structure is typical of an alloy that has cooled slowly after crystallization has taken place.

The stony-iron meteorites are made up of nickel-iron and iron-magnesium silicate minerals in approximately equal amounts. The silicate mineral is generally olivine, $(Mg,Fe)_2 SiO_4$, occasionally with some pyroxene, $(Mg,Fe)SiO_3$. Commonly, the olivine occurs as rather large, rounded grains in a spongelike network of nickel-iron. It is interesting to note that a meteorite of this type, weighing about 1,500 pounds, was found near Krasnoyarsk in Siberia in 1749, and was seen by the Swedish traveler P. S. Pallas in 1772, who recognized that it must be of extraterrestrial origin. Stony-iron meteorites of this type have since been known as pallasites in his honor.

Stones are the most abundant meteorites. They also show the greatest variety in composition and structure. They are divided into two groups on the basis of structure: the chondrites and the achondrites. The first are so named because of the presence of chondri, or chondrules—small (usually about one millimeter in diam-

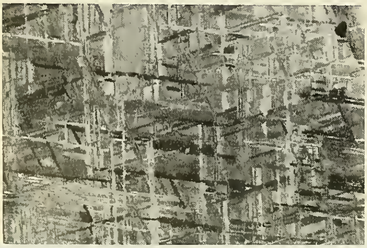
Achondritic stone shows rough texture.

Chondritic stone has olivine, pyroxene.



Stony-iron, pallasite, contains olivine.

Black carbonaceous chondrite, *above;* Widmanstätten figures, *below,* in iron.



eter), rounded bodies consisting of olivine or pyroxene. The achondrites (without chondri) are much more coarsely crystallized than the chondrites. Chondrites are much commoner than achondrites, making up more than nine-tenths of all stones.

Upon mineralogical analysis, most chondrites prove to be a mixture of olivine and pyroxene, generally with between 5 and 20 per cent nickel-iron, about 5 per cent troilite, and about 10 per cent plagioclase (sodium calcium aluminosilicate). Many achondrites are similar to chondrites in composition, except that they contain little or no nickel-iron. Some, however, contain a considerably larger proportion of plagioclase and are thus known as basaltic-type achondrites, since their composition is like basalt, a common volcanic rock.

One small group of chondrites is remarkably different in its chemistry and mineralogy. Known as the carbonaceous chondrites, they contain a notable percentage of free carbon, which gives them a black, sooty appearance. While all other meteorites contain essentially no combined water, the carbonaceous chondrites contain 10 per cent to 20 per cent. They also contain organic compounds in small amounts, as well as free sulphur, d calcium and magnesium sulpha s. Instead of olivine and pyroxene, th ir silicate mineral is largely serpen ne (a hydrated iron-magnesium silica). They contain no nickel-iron.

Only nineteen carbonaceous ch ndrites are known: all of them w re seen to fall and were picked up s n after. Indeed, if they were not collec d immediately after falling they wo ld not have survived very long: of ne of them it is recorded that, w placed in a glass of water, it di tegrated and gave off a nasty od ! (This stench was probably sulp reted hydrogen, produced from ea y decomposed sulphides). The fi t-known carbonaceous chondrite fel at Alais, in France, on March 15, 18 : it was sent for analysis to the fam us chemist Berzelius, who expressed g at doubt as to its meteoritic origin, si e it was so different in composition fr m all other meteorites.

However, the obvious differen es between the carbonaceous chondr es and what we may call the olivine- y-roxene chondrites have obscured e remarkable similarity. Dr. Wiik a Finnish chemist who has analy d many meteorites, pointed out in 1 6 that, if analyses of these two types f chondrites are recalculated on a -

	IRONS	STONY-IRONS	STONES Achondrites	 Olivine-Pyroxene Chondrites	 Carbor aceou Chondri
Serpentine *hydrated magnesium-iron silicate*					up to 6
Free Sulphur					1-2%
Combined Water					10-20
Free Carbon				little or none	1-5%
Plagioclase *sodium calcium aluminosilicate*		0-15%	up to 60%	about 10%	
Pyroxene $(Mg, Fe)SiO_3$		0-30%	0-100%	1-60%	
Olivine $(Mg, Fe)_2SiO_4$		0-50%	0-100%	0-70%	
Schreibersite $(Fe, Ni)_3P$	about 1%	0-3%			
Troilite FeS	about 1%	1-5%	about 1%	about 5%	little c none
Nickel-Iron	almost 100%	about 50%	little or none	5-25%	

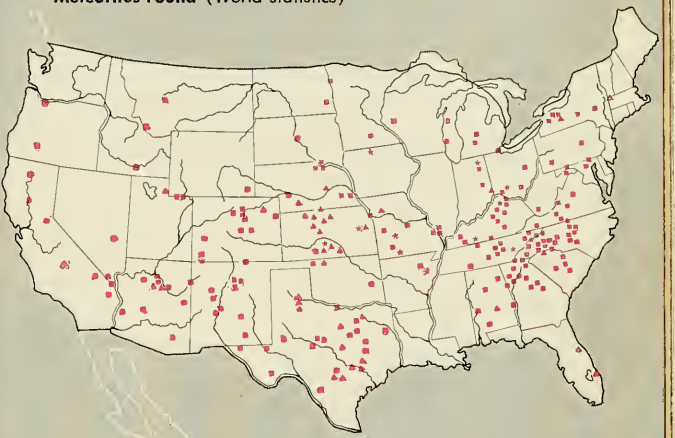
t-, carbon-, oxygen- and sulphur-free
sis, their elemental composition is
ry similar. This is to say that the
emical composition of the common
vine-pyroxene chondrite is that of
arbonaceous chondrite from which
ter, sulphur, carbon, and some oxy-
n have been removed. The conver-
n of a carbonaceous chondrite may
produced by a natural heating proc-
. Serpentine decomposes on heating
ove about 500°C., to yield olivine
d pyroxene. If carbon is present, a
tural smelting will take place, reduc-
g some of the combined iron to
tallic iron—another constituent of
olivine-pyroxene chondrites.

HAVING described the principal
mineralogical characteristics of
teorites, we may now consider their
gin. H. A. Newton, as long ago as
186, summarized the numerous the-
ies in the following manner: "They
ne from the moon; they came from
earth's volcanoes; they came from
sun; they came from Jupiter and
other planets; they came from
ne destroyed planet; they came
om comets; they came from the
bulous mass from which the solar
stem has grown; they came from
fixed stars; they came from the
pths of space."

Truly a plethora of possibilities,
ne of which, however, can reason-
ly be eliminated. Origin from the
th's volcanoes is inconsistent with
teorites' composition, which, ex-
t for the small group of basaltic-
e achondrites, is different from all
lcanic rocks. Moreover, volcanoes,
hough powerful, do not produce
ugh energy to put rocks into orbit!
is also difficult, if not impossible,
derive meteorites directly from the
n, the moon, Jupiter or the other
nets. Nonetheless, meteorites pre-
mably originated within our solar
tem since, like all other bodies in
s system, they revolve about the
n. For many years it has been
umed that meteorites are fragments
a disrupted planet that once existed
ween Mars and Jupiter. This region
the solar system is occupied by
umerable small objects (some of
m as much as three hundred miles
diameter) known as asteroids.

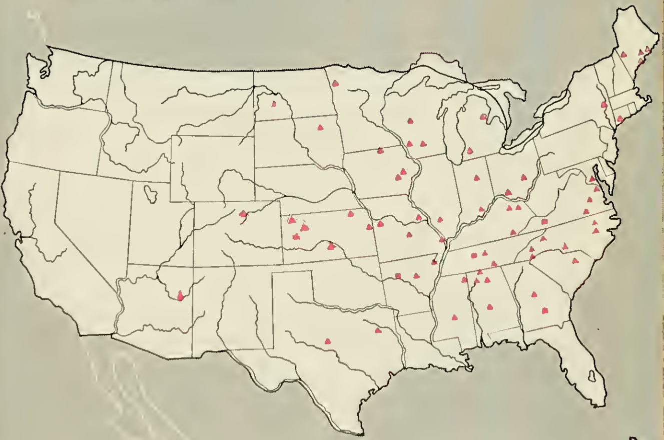
The origin of both meteorites and
eroids from a disrupted planet im-
s that the disruption probably took
ce early in the evolution of the solar
tem and that most of the fragments

Meteorites Found (World statistics)



Type	Number	Per Cent
🟥 Irons	503	59
★ Stony–Irons	55	6
▲ Stones	304	35
Total	862	100

Meteorites Seen to Fall (World statistics)



Type	Number	Per Cent
🟥 Irons	42	6
★ Stony–Irons (Not seen to fall in U.S.)	12	2
▲ Stones	628	92
Total	682	100

were swept up soon after. Such a disruption would probably have bombarded the other planets with fragments very much larger than the average meteorite of the present time. To be sure, no evidence of bombardment on such a scale has been recognized yet in the rocks of the earth's crust. some of which date back over three billion years. Still. the innumerable craters on the moon are thought to be due to the impact of meteorites: in the absence of an atmosphere, little weathering or erosion takes place on the moon, and these craters have thus been preserved unchanged.

IRONS, stony-irons. and achondrites can be explained readily as originating from the disruption of a planetary body. Like the earth, such a body would presumably be differentiated by the force of gravity into an iron core and a stony mantle, the stony-irons coming from a transition zone. Certain features of the chondrites, however, are not so easily accounted for. The composition of the carbonaceous chondrites shows that they have never been exposed to temperatures above 500°C. and have probably always been at much lower temperatures. Further, the texture and structure of both carbonaceous chondrites and olivine-pyroxene chondrites indicate that they have not originated in any body with a considerable gravitational field. Many of them are very porous and friable—some to such a degree that they can be crumbled in the hand—a condition that indicates that they were not consolidated under pressure. The nickel-iron in the chondrites, moreover, is intimately mixed with low-density silicate minerals and shows no sign of gravitational segregation.

DR. MASON, Curator of Mineralogy, has based this article on studies of the extensive collection of meteorites belonging to THE AMERICAN MUSEUM.

One of the recent discoveries of astronomy is that outer space is dusty. It is now believed that more material exists in the universe in the form of dust than is aggregated into stars. The composition of this dust is unknown, but it is presumably made up of the same chemical elements that compose the larger bodies. Perhaps the carbonaceous chondrites are representative of this primordial dust.

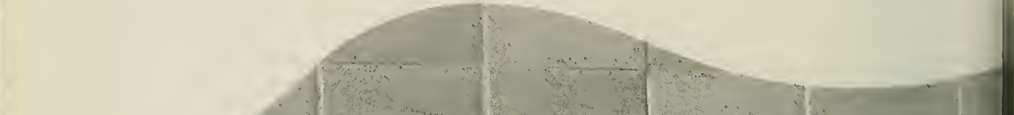
We have seen that heating processes would convert carbonaceous chondrites into olivine-pyroxene chondrites. Consider the possibility that the solar system may have originated as an immense cloud of primordial dust, which gradually cohered into moderate-sized masses, of which the chondritic meteorites are a sample. These masses—"planetesimals," as they have been called by Chamberlin and Moulton—then aggregated to form the planets. Aggregation into such large bodies would produce heat sufficient to melt them at least partially, and this melting would result in a gravitational separation of the nickel-iron from the silicate.

In this view, the breakup of a planet—presumably situated between Mars and Jupiter—produced the asteroids, some fragmental representatives of which still stray into the earth's gravitational field and eventually land as the irons, stony-irons, and achondrites. But the carbonaceous and the olivine-pyroxene chondrites, on the other hand, would not have derived from the planetary disaster. Instead, in this view, these meteorites would represent the "fossil" planetesimals, leftovers—in considerable numbers—from the initial cloud of cosmic dust from which our solar system grew.

AERIAL VIEW of Meteor Crater, Arizona, *above*, shows the deep gouge left by impact of a meteor during prehistoric times. At right, the camera looks north, from rim to rim, across the 600-foot-deep crater, a distance of 4,000 ft.

The Biology of Man

New Museum Hall shows evolution and function of human organis

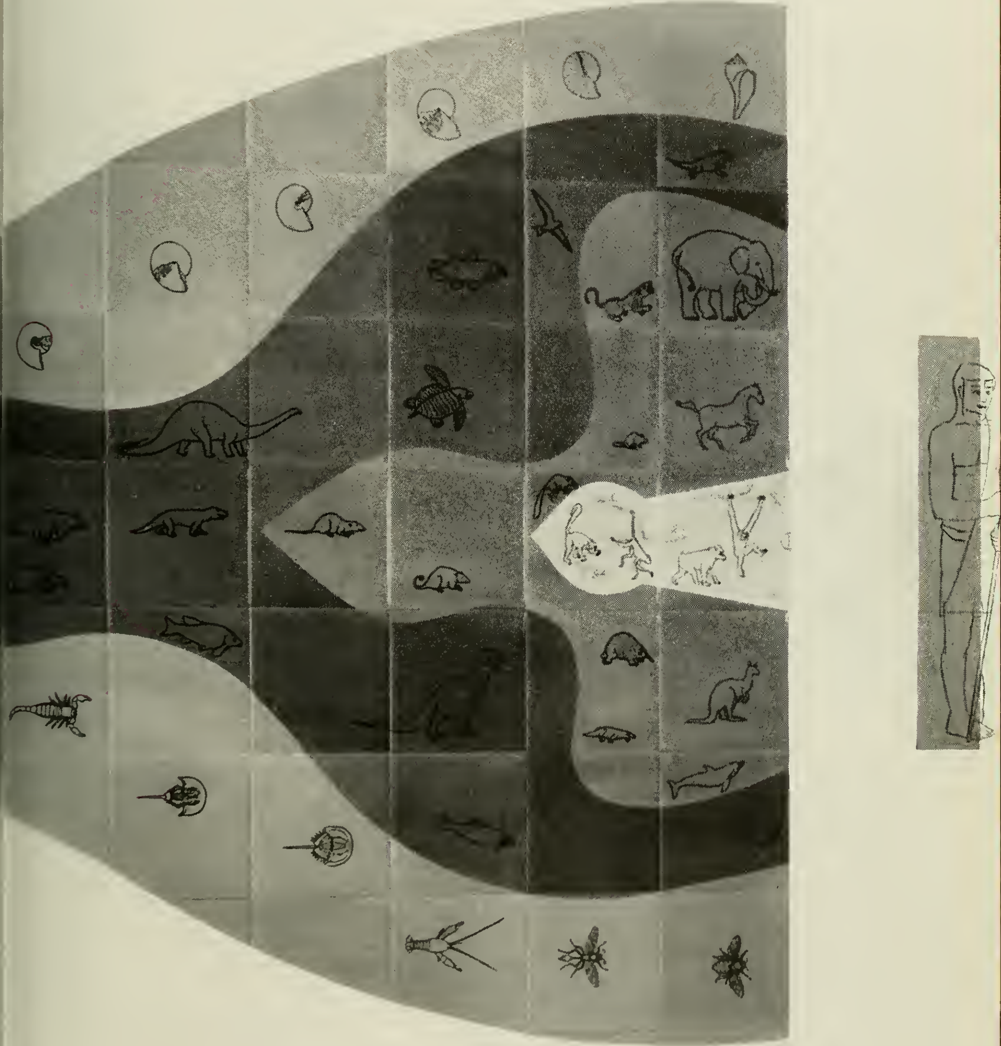


A primary purpose of The American Museum of Natural History is to contribute to the understanding of man's place in the world of nature and to communicate that knowledge to the public. The Museum's newest exhibit, which shows man as a physical entity, dramatically furthers that purpose. It is the first in a series planned to present organic man and his culture.

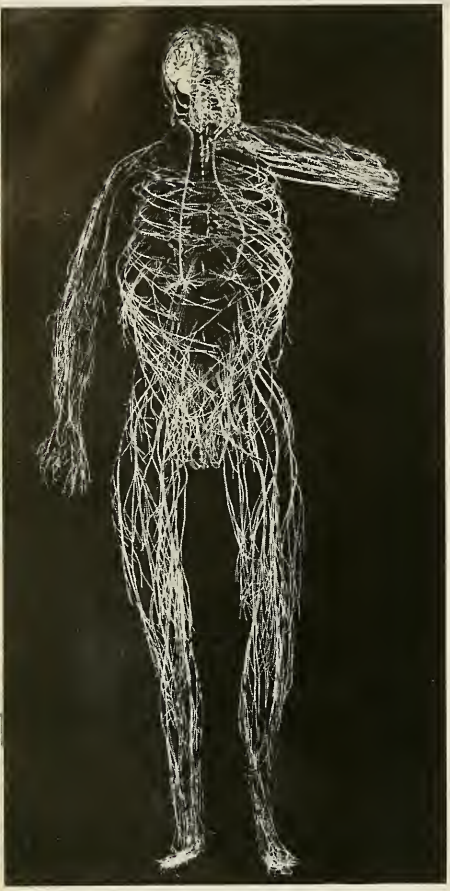
The exhibit, called the Hall of the Biology of Man, consists of three subdivisions, two of which were opened to the public late in March. The first section is concerned with human evolution and the relationship of man to organisms that preceded him in time. The second section is devoted to the development of the human organism itself—from the basic unit of life, the cell, to a functioning body of infinite complexity. The third will show man as a member of a biological group with its own environment.

Obviously, the scope of such a subject poses stringent exhibition requirements. To this end, new techniques and materials have been utilized, and old ones put to new uses. One example lies in etching figures on a series of clear plastic sheets, which are then superimposed on each other. When edge-lit, the sheets transmit light to the etched areas, producing the illusion of movement within the figure being displayed.

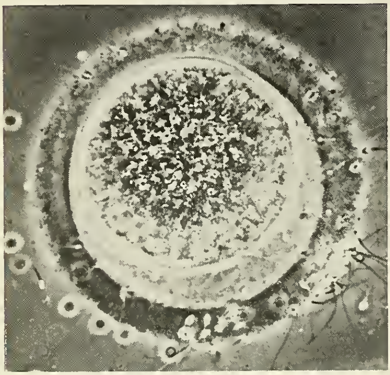
Readers of Natural History are invited to preview high lights of the exhibit on these pages.



Evolution, from invertebrates through vertebrates, mammals, primates, and man, is dramatized in varicolored tiles.



Nervous system was constructed in miniature with strands of brass wire. The brain and spinal cord are of wax.

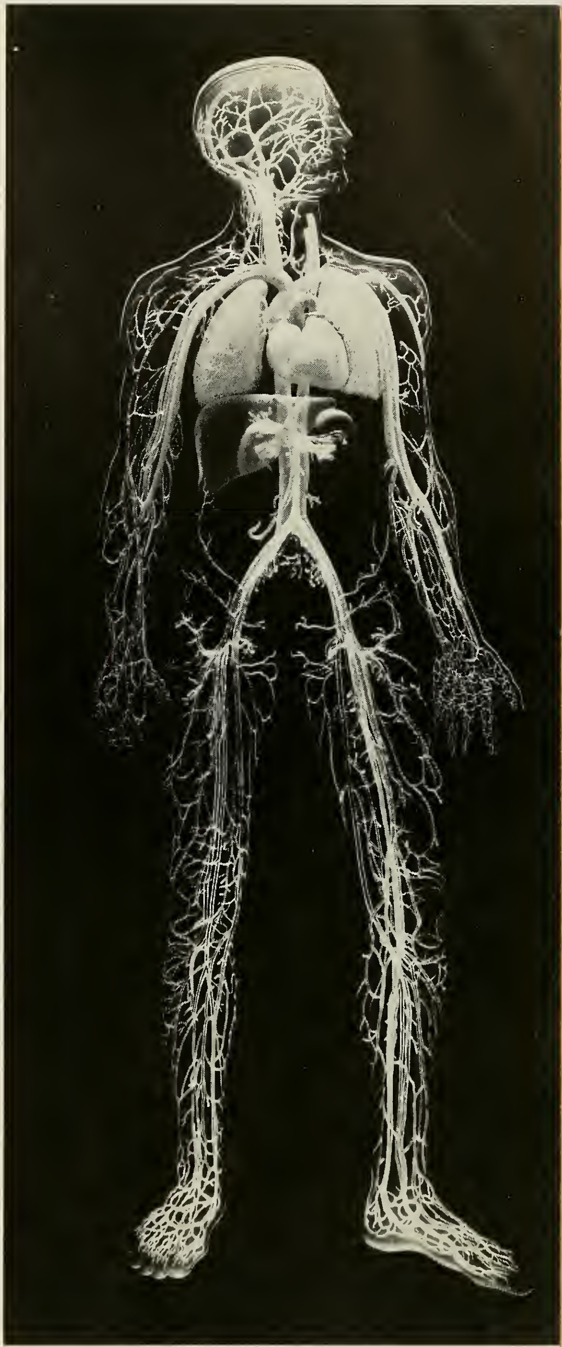


Five- by eight-foot photomural of human ovum and sperm begins exhibit demonstrating development of embryo.

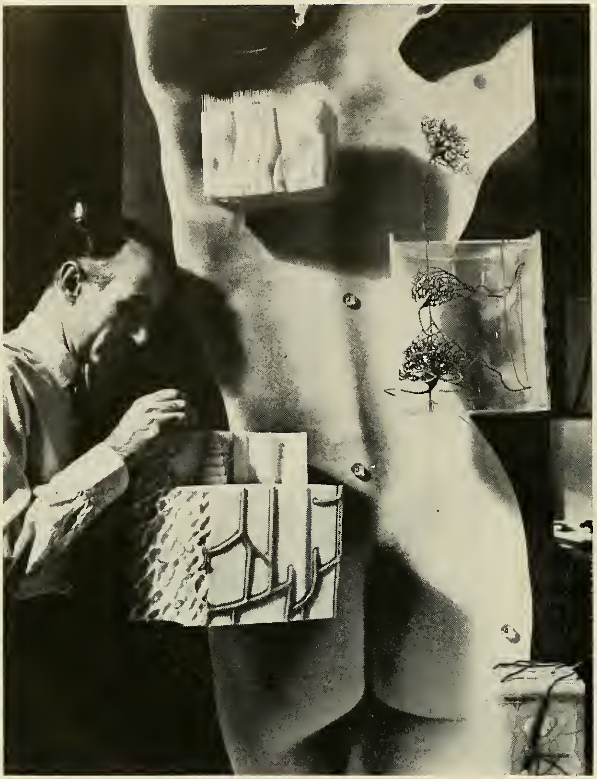
Panel being installed shows in detail multiple movements made by leg and pelvis in process of taking one stride.

Leg articulation, *right*, is explained by bone in foreground, behind which are metal cutouts against a painted background.

Plaster model of human birth, *below,* is culmination of a series of exhibits on history of a new organism's development.



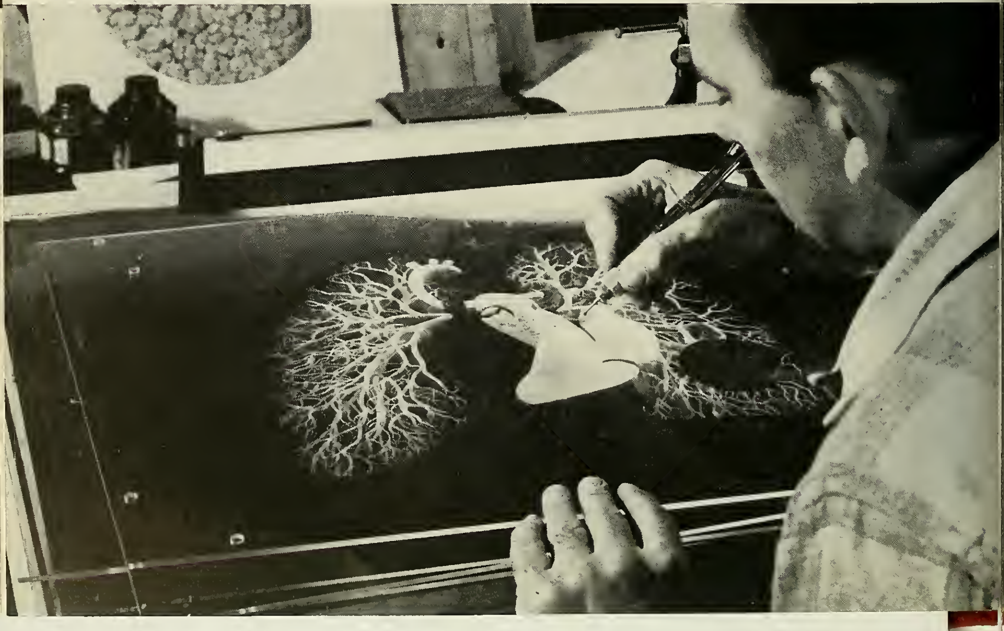
Routings on laminated sheets of clear plastic are edge-lit to produce life-sized model of human circulatory system.

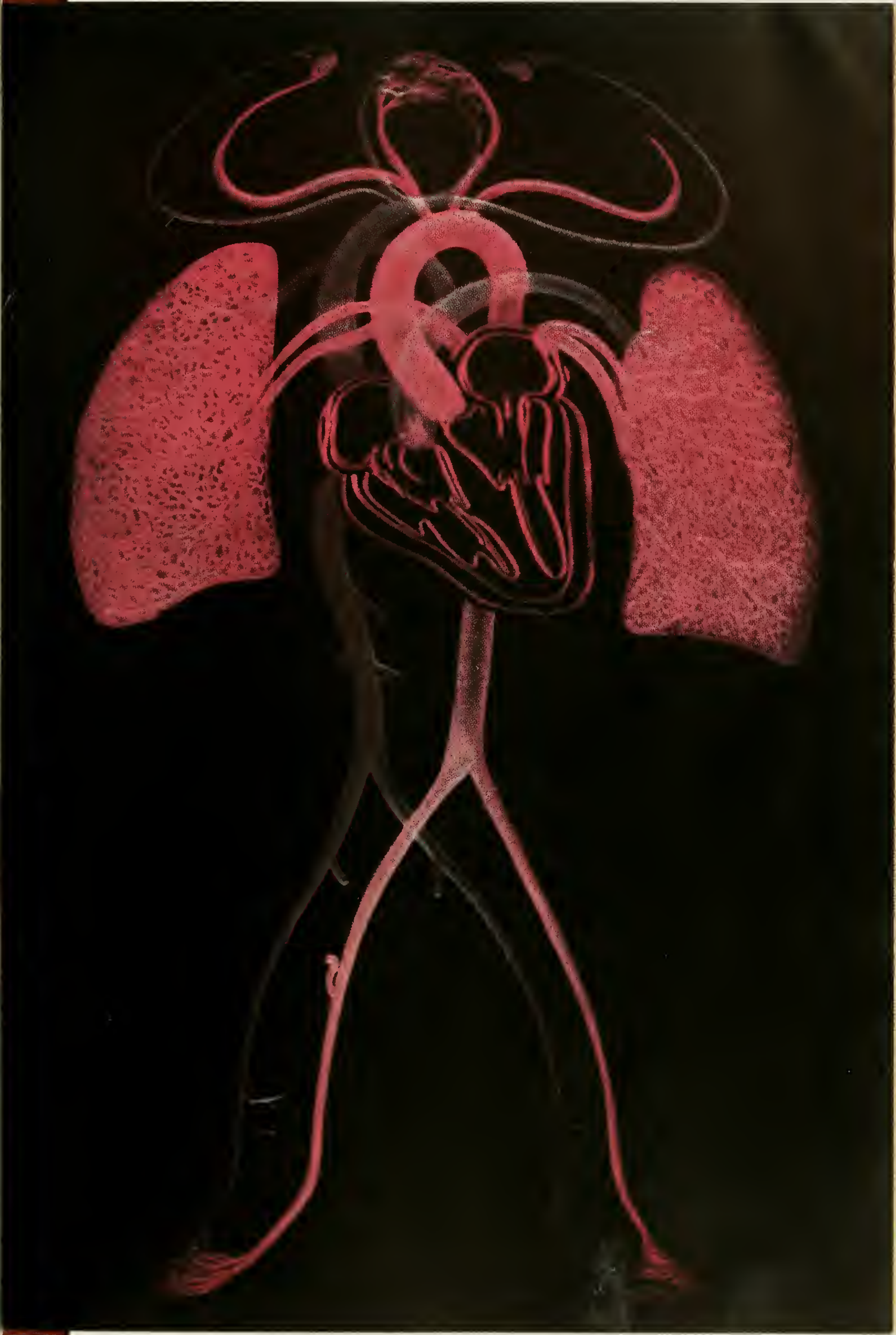


Plastic, wax, and wire were utilized in display showing how cells are organi into tissues and structures, including the trachea, spinal cord, bone, and skin.

Model of circulatory system, *ri*, is made of successive plastic sheets. F of light on edges makes heart appea beat and simulates movements of bl

Routing is done with fine engrav tools on successive acrylic sheets, *bel*. These. superimposed on each ot are fastened together for final disp





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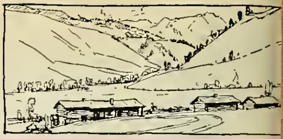

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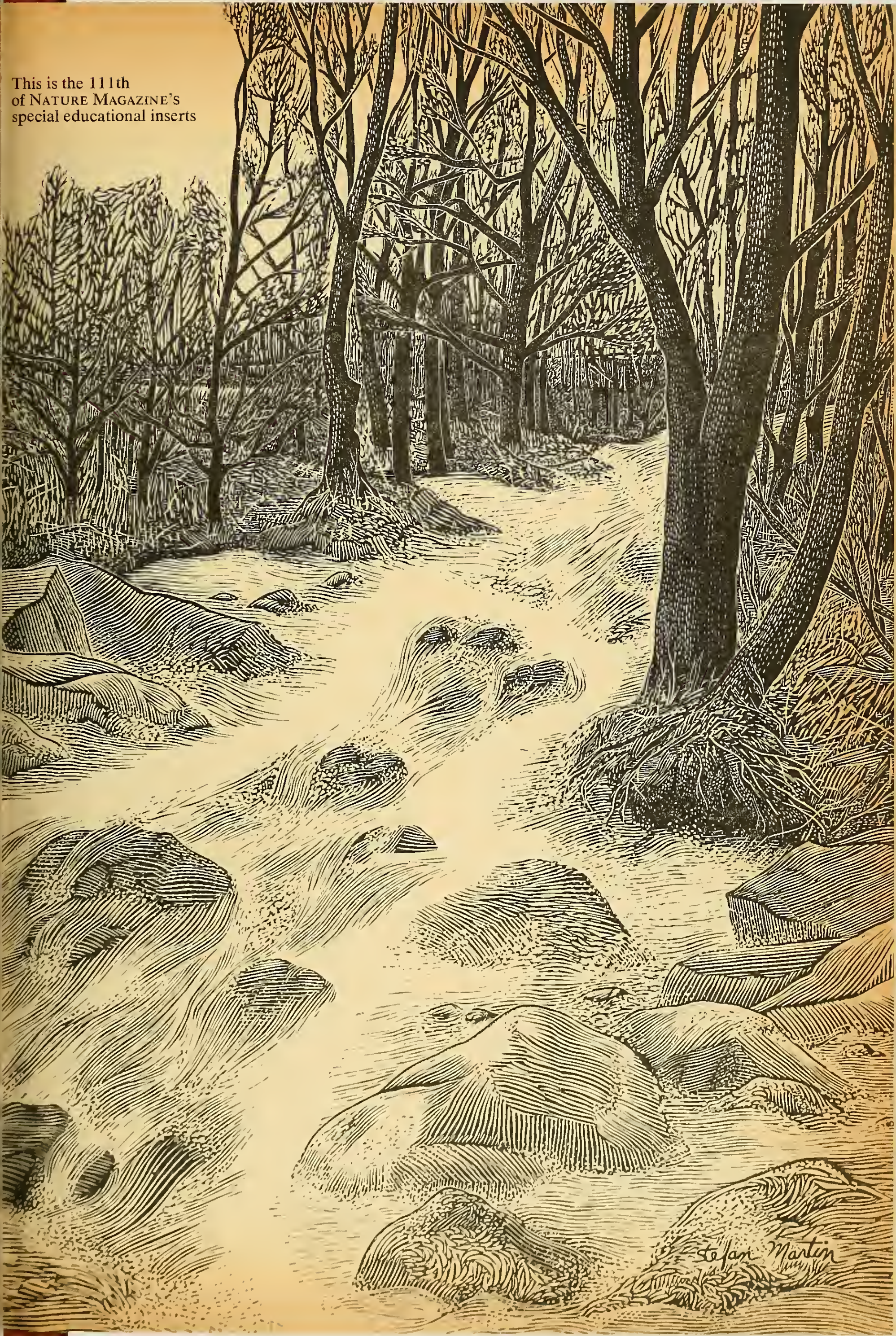
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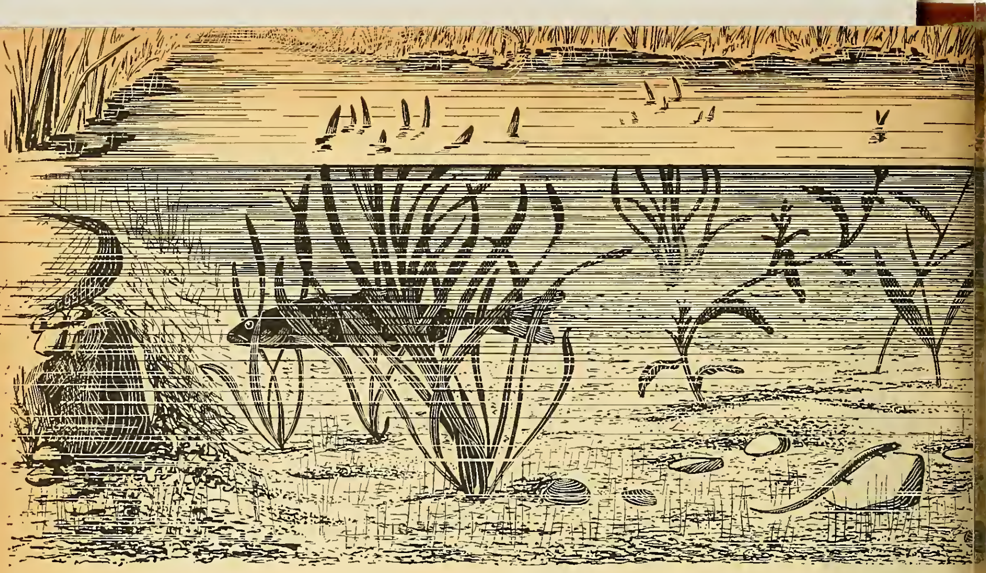


STREAM EDGES

Stream's relation to its shore or bottom may sharply affect man

By E. Laurence Palmer

In and out of nature, the most dynamic, interesting, and challenging situations are usually found where different elements meet. Hunters find their greatest rewards at the juncture of field and forest. Trappers succeed best where land is bordered by water. Men find their most wholesome enjoyment of life where they can mix the satisfactions associated with periods of rest with vigorous physical exercise, or muscular activity with mental stimulation. The greatest rewards in scientific research are in explorations of the border territory between the biological and physical sciences, particularly when such studies satisfy human demands for the practical, mental, moral, and aesthetic aspects of life.

In this discussion we will examine the events that take place at the points where a moving stream of water makes contact with a fixed bottom or shore.

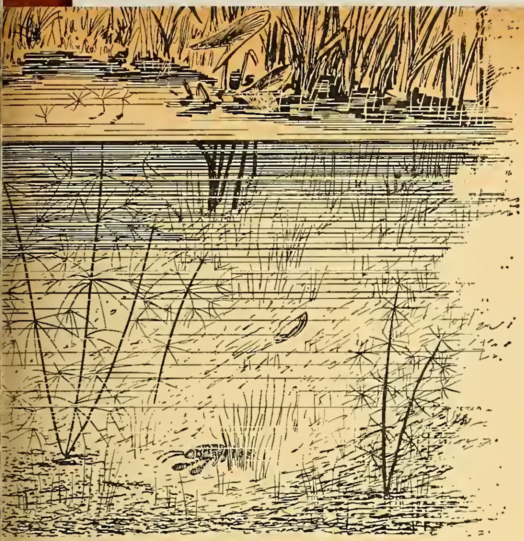
There are good reasons why major centers of human population are usually located at points where the land meets a stream of water—a stream that serves to bring in wealth and take away the wastes of civilization. At the water's margin are to be found the roots of both the problems and the opportunities of the world's human races. Wars have been, and will be, fought by people who hope to maintain or gain access to flowing water. Similar wars are also fought by mammals other than humans, and by plants and other living organisms. There must be a "give and take" all along the line, and rarely, if ever, can we use a ruler to map the course of a stream —or, for that matter, a society, human or otherwise.

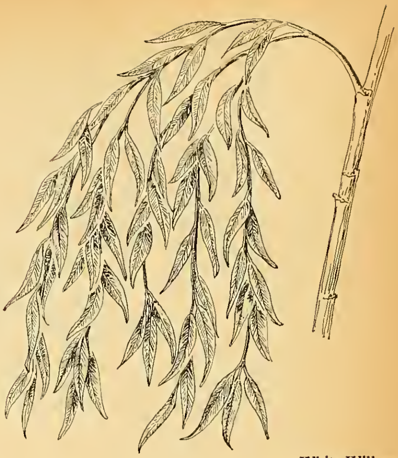
In this insert we are concerned with the dynamics of a moving stream, its fixed and confining earth, and with the activities taking place in the neighborhood. A walk along the banks of any stream will enable the reade to enlarge on the information and observations presented on these pages; but it will be worth while to carr through some of the suggestions that follow.

Most people have difficulty resisting a temptation t throw objects like sticks and stones into an inviting bod of water. We like to see the water splash, and find ou whether the objects sink or float. Objects that are heavie than the volume of water they displace sink, while thos that are lighter float. Floating objects in moving wate constantly change their positions, creating an endles variety of new situations wherever they go.

Select, then, some stream a few feet wide where, fo a hundred feet, the depth is relatively uniform and th speed of the water reasonably constant. At ten-foo intervals along the bank, place sticks, stones, or othe distinctive markers. Above the first upstream marker tos an object into the water so that it will be carried alon by the stream. A snowball or a small stick will serv the purpose. Then notice the number of seconds it take for the floating material to move a hundred feet downstream. If you throw in several objects, it is unlikel that they will all move downstream at the same rate. Yo may determine the average rate of movement, but d not forget that movement is rarely uniform. Decide that on average, the water moves by a given point in th stream at a given number of feet per second.

To the tip of a pole—about the size of a fishpole— attach a string a few feet long. To the free end of th string tie a stone heavy enough to hold the string ver





White Willow

tically in the stream with the stone resting on the bottom. At equal intervals on the string tie markers, so that you may easily measure the stream depth at any point. Imagine that a vertical sheet of water is moving downstream past any point, and determine the size of this sheet of water with the help of your measuring device. In this way you should have little difficulty in estimating the number of cubic feet of water passing a given point in one minute. Since there are 7.43 gallons in a cubic foot, you can approximate the number of gallons the stream carries per second, or per minute, if you prefer. This figure will be of importance to you in describing the stream with some degree of accuracy.

It is the moving wall of water that does much of the work in changing our stream edges. Some objects float in the current, and do little or no damage to the stream edge. Others remain fixed on the stream bottom without effect on the bottom itself, although they may smooth off the rough edges of objects passing over them. Much material bumps along the bottom and sides of the stream —and it is this that most affects the stream bed.

Since water is heavier than air, a stone submerged in water weighs less than it does in air, displacing the same amount of substance in either case. This means that a stream may move some remarkably "heavy" material. By observing the movement of substances along the bottom of a stream, you may roughly estimate the speed of the water in a stream. Here are some suggestions to aid your estimation of water speeds.

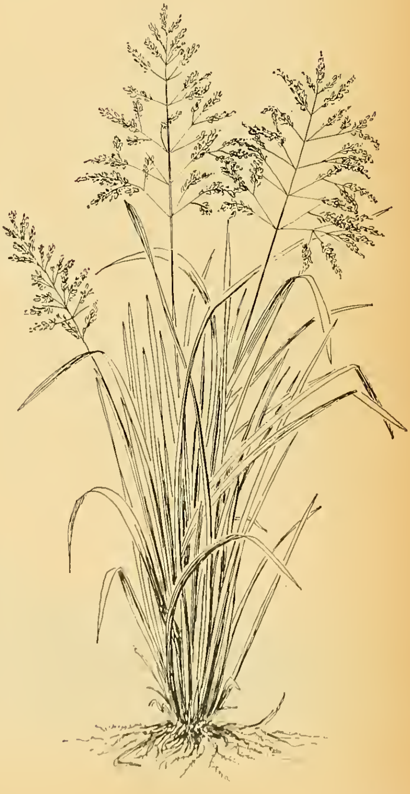
Water flowing at three inches a second, or about three-eighths of a mile an hour, will move fine clay along the bottom of a stream, if the clay is loose.

A sluggish river, flowing at six inches a second—about three-quarters of a mile an hour—will be able to move fine sand along the bottom.

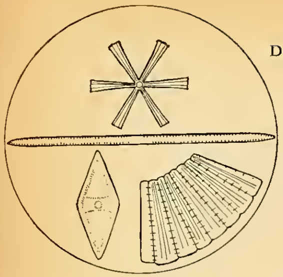
A river flowing at eight inches a second, or about one mile an hour, will move coarse sand.

A brook flowing at one foot a second—about one and one-half miles per hour—will move fine gravel.

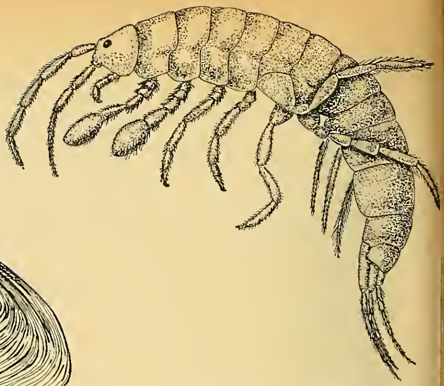
A stream flowing at two feet a second, or three miles



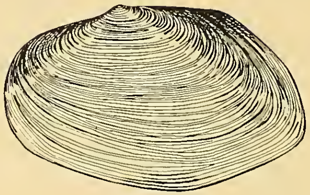
Kentucky Bluegrass



Diatomaceous Oozes



Fresh-water Shrimp



Fresh-water Mussel

an hour, will move loose pebbles one inch in diameter.

A swift stream, flowing at about six miles an hour, will move ten-inch stones.

A torrent that flows at eleven miles an hour may move forty-two-inch stones.

Cloudburst waters flowing at twenty-two miles an hour may move boulders weighing up to 250 tons.

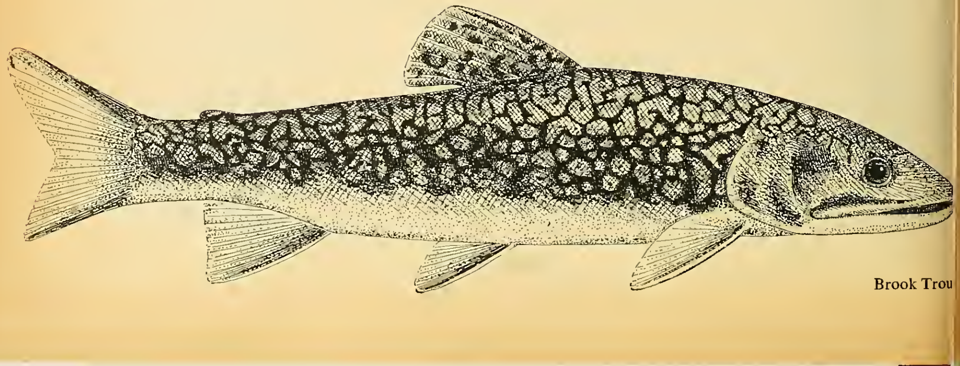
The width of a stream, of course, affects the speed of its waters at any given point, and the stream flows more rapidly at its narrowest points. It is important to realize this fact if for any reason it is desired to make the stream co-operate in changing the nature of its bank.

It might be thought that, if the water in a stream were moving at four miles an hour—at a speed about equaling that of a good fast walk—a doubling of the stream's speed would enable it to move objects weighing twice as much. As a matter of fact, doubling the stream's speed increases its carrying power not by twice, but by sixty-four times. This means that if a stream were wearing away its banks by moving pebbles weighing one ounce, and its speed were doubled, it would be capable of moving rocks weighing four pounds. If its speed were doubled again, it would move rocks weighing 256 pounds. From these figures, it is obvious that the movement of water over fixed earth may become a matter of the greatest importance to humans.

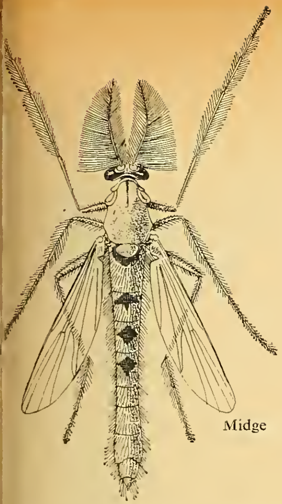
Water, moving over the surface of sloping land, carries with it materials that may be of great value to the landowner. Such movements of small amounts of valuable soil may, over the course of time, prove more significant than the spectacular erosion produced by flash floods. Sheet erosion is not as noticeable as the gully-type of erosion, but it may be even more wasteful.

It may be noticed, during a walk along a stream after a heavy downpour, that the stream's color is not uniform. The water flowing over mud or clay is of a different color than that which flows largely over rock. It may also be noticed that small streams flowing into larger streams also vary in color, and that those coming from sod-covered areas are clearer than those originating in cultivated land lacking a binding sod. If you are a fisherman, you have probably learned that the fishing varies with respect to locality—the fish seem to know that, where stones and debris are turned over on the bottom of a stream, aquatic insects are washed from their hiding places as items of food.

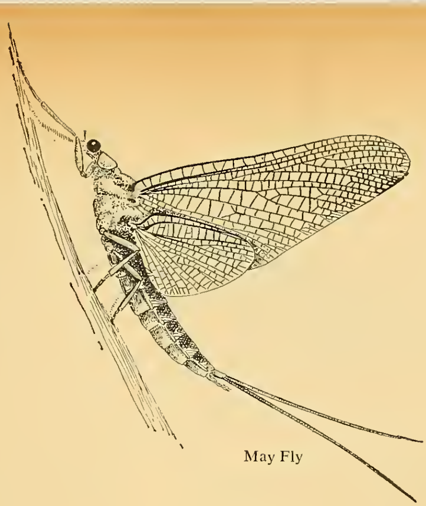
The management of stream banks is a science that calls for the application of engineering, biological, and other technical skills. For example, it is recognized that the volume of a stream varies over the course of the year and that the work done by a stream in flood may create conditions conducive to the survival of useful fish in times of drought. Stream bank managers know that



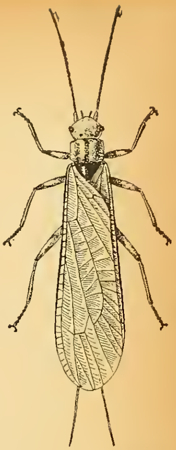
Brook Trou



Midge



May Fly



Stone Fly

shallow, slowly moving, unshaded waters may become too warm for many species of fish, and thus they plan to provide needed depth, speed of current, and shade.

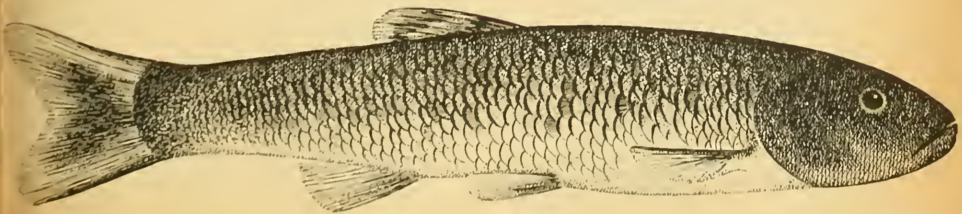
Generally speaking, the more important schemes employed in managing streams for fish include the digging of channels, to provide fish with an opportunity to move from a threatened area to a better one. Such channels guarantee that a fish may also have a sufficient volume of water in which to survive. Also employed are deflector dams of boulders, large stones, anchored logs, or even concrete walls. These latter serve to prevent dangerous undermining of stream banks, and also to allow undermining where it is wanted. The deflectors concentrate or dissipate the flow of water. Some are designed with holes in their bases through which a stream of water may flow at a high rate of speed to flush out the bottoms of downstream holes. Others have V-shaped tops that guide the fall of water to scour out downstream holes. Single-wing and double-wing deflectors provide a maximum of stream useful to trout in a given mile of stream bed.

A well-planned stream bank uses the anchoring qualities of plants that grow down to the edge of the water, and limits the access of cattle and other animals that may destroy the protective sod. Stream bank managers use plants to hold the stream in place, and to this end they may plant large numbers of willows to serve as soil anchors. The roots of the willows may also provide hiding places for fishes of different sizes and species, with the smaller surviving until such time as they might be of value as food for the larger. Fencing portions of the stream border also helps in anchoring the stream edge.

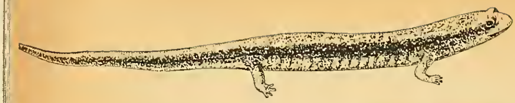
Dams may be useful in stream and stream bank management, and may be constructed of boulders, logs, or combinations of stone, earth, and wood. Parts of these dams may be modified to utilize the retained water for special purposes, although the dams serve primarily to store water against times of water shortage. Engineers know how to construct dams, which will build up useful accumulations of silt, or which, on the other hand, will keep such accumulations at a minimum. Some man-made dams rather closely resemble beaver dams, and make use of brush in their construction.

The building of structures designed to change the nature of a stream bank takes into account not only the large differences that may exist in a stream during the several seasons of the year, but also the expense and effort necessary to maintain them over a span of time.

The interests of different animals that haunt a stream bank may often conflict. Man, for example, may wish a mudbank to maintain a pond where his ducks may breed. Such banks may also provide ideal earth into which muskrats may burrow—but the muskrats cause major leaks in the dams, built by men at considerable expense in time, money, and effort.



Horned Dace



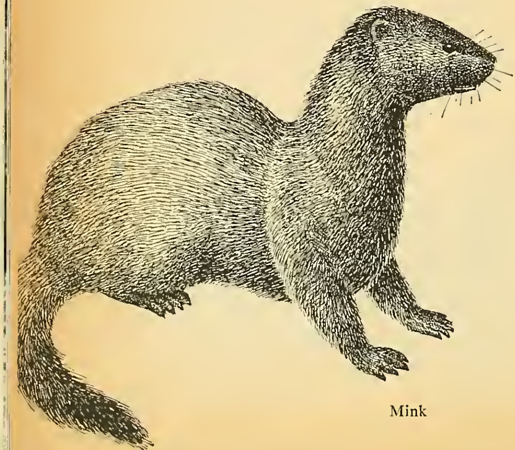
Two-lined Salamander

It should be interesting to investigate the variety of holes to be found along and in stream banks, made by various organisms. Some of the holes may be underwater, some at water's edge, and others well above the water mark. The tabular matter accompanying this insert considers a number of these "hole-makers."

Underwater holes in streamside banks may be vital to mammals like beavers, which must reach their dens in a bank or in a house under the ice of winter. Such entrances may be at the deepest point in the waterway near the bank, and continuous use of the entrance may make the ice thin at that point. It is well to realize this fact when you start to walk around a beaver house in bitter winter weather! The underwater entrance allows the beavers to carry food into their dens and to attain a degree of safety from enemies. Muskrats, too, are able to reach their houses from underwater without risking exposure to their many enemies.

Many other animals use similar techniques. Crayfish may burrow in a stream bed in search of food and safety. Frequently, the resulting channels open up spaces through which a small stream of water may begin to flow, and the bottom of the stream is thus kept active in the production of small organisms important to the larger as food. Even small burrows may serve this function.

Many aquatic insects also burrow in the stream bottom, and some burrow into the banks at or above water's edge. All these burrows, taken together, create considerable changes in the stream bank. Turtles may burrow into the stream bed; some may occupy abandoned muskrat burrows along the bank. In some cases such used or abandoned burrows may be appropriated as shelters by the snakes that live in our waterways. In the South, where water moccasins are found, one should investigate the tenants of such burrows with respect!



Mink

Salamanders of a number of kinds frequently modify stream banks, even if in a rather modest way. Ordinarily, these small amphibians burrow in mud or under pebbles on the bottom; but wherever they go they may leave an open area behind them through which the water may increase its flow and consequently its work. Anything that disturbs the stream bottom or bank may, in the course of time, effect changes in the stream itself.

Not infrequently the muddy bottoms of streams provide ideal burrowing sites for many of the fresh-water mussels. The mussels supply food for fishes, which burrow in the mud in search of them; and in this way the mussels help to modify the stream bottom.

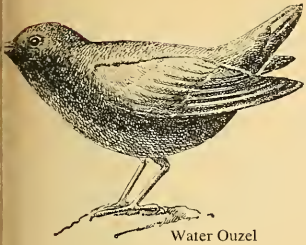
There was a time when the shells of fresh-water mussels were so abundant in our streams that they had a considerable economic value. "Pearl" buttons were cut from the shells, and from the resulting waste came material useful as an adjunct to poultry rations. Lime from the shells constituted a fertilizer for improvement of both the chemical and mechanical nature of agricultural soils. Since many of the fresh-water mussels spend a part of their life histories as parasites on fishes—particular species of mussels favoring particular species of fishes—some remarkable situations develop. Some of these are mentioned in the chart section of this insert. Heavy populations of mussels tend to build up the bottoms of streams in favorable places, so that we have "shoals" owing partly to their abundant presence. Some such shoals have had a bearing on power development along a number of American streams and rivers.

In the 106th insert of this series it was pointed out that some fresh-water mollusks are significant in their relation to public health, and it is probably true that the mollusks, which can change the courses of mighty streams, may in the long run be more important than great armies or great dams.

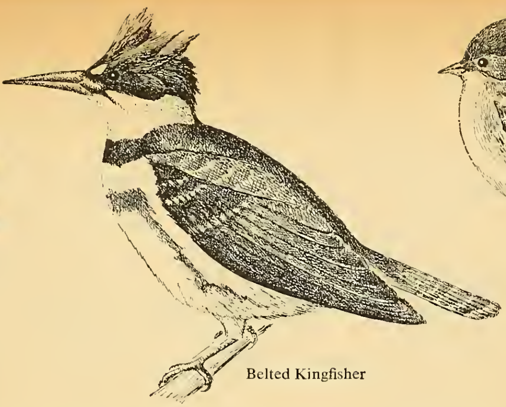
While problems of sanitation and economy, as they bear on stream banks, are important, they should not be allowed to become exclusive. A sandpiper runs along the edge of a stream. A kingfisher flies into its streamside nest, to the delight of those who enjoy watching stream banks for aesthetic reasons. Men consider the monetary promise of a stream flowing through a gorge, but they should also consider the song and antics of the water ouzel. Few who have watched this bird in its natural environment would hesitate to defend its presence, or would advocate its elimination in the interests of "progress." Less vigorous, but perhaps better known, are the phoebes that haunt walls of glens from coast to coast.

Perhaps it is such glens that offer the greatest study rewards. Their waters run swiftly at times, and as a mere trickle at other times. Exhibited in the glen is the raw power of moving water—the power to scour, to develop plunge basins, to tear away vegetation. In its quieter phases, the water of the glen performs the slow, steady, plodding work which may, over the course of the years, produce even more important changes.

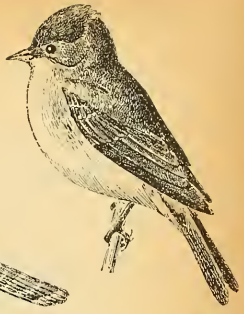
Perhaps it would be of more value to study a single stream bed and compare it with one in which the stream waters flow over an entirely different sort of bottom, and with an entirely different volume and variation in flow. It should be remembered that this discussion dwells primarily on stream banks where the flow of water is



Water Ouzel



Belted Kingfisher



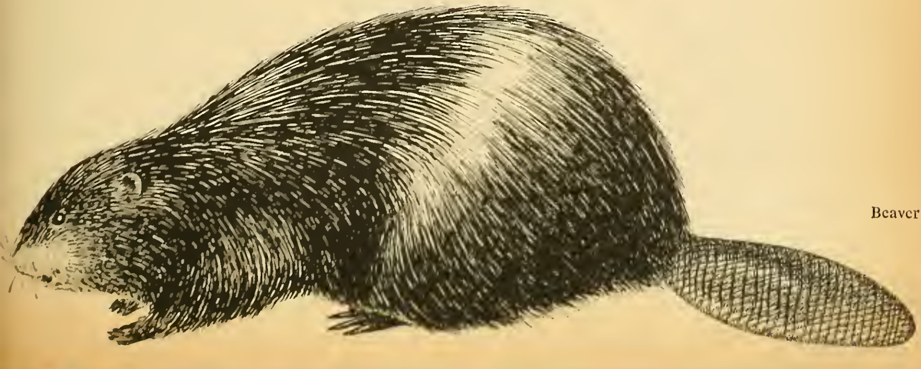
Phoebe

not strictly cyclic, as it is on a tidal flat. In our streams, any object that moves past a given point in the watercourse seldom, if ever, returns.

In studying the management of the stream edge we must recognize that the edge is rarely stationary. It moves up the bank when in flood; down when in drought. While in tidewaters this movement is cyclic and can be predicted with great accuracy; in a stream this is rarely so. A fiddler crab at the edge of the tide burrows down as the tide goes out. When the tide comes in the crab emerges to roam, feed, and breed. A stream margin presents a different pattern. In time of flood, the plants and animals of the edge may be submerged or partly submerged for a few hours, days or weeks, and this period may be followed by a drought of indefinite length of time. Sometimes such submergences or exposures are accompanied by extremes of heat, light, and abrasion, further complicating the survival problems of the creature involved. This situation is met in part by the ability of some stream edge plants and animals to move as the need arises. On the other hand, many organisms can survive if one part of the creature can remain out of the water while another part is submerged. When a beaver dam is first established, the trees whose roots are at first submerged may appear to prosper, but if the submergence continues the roots cannot continue to function because the air has been cut off. Then, of course, the roots and the trees die—as you may see at the edge of any pond created by a growing beaver colony. If the value of the harvestable beaver pelts exceeds the value of the wood the colony may in time be considered an asset by the landowner. If not, then the work of the beaver must be considered as destructive unless other values change.

The 60th insert, published ten years ago, was titled "On the Level," and went into considerable detail about the use of dams in controlling the water level along streams. It emphasized the difficulties of managing this level so that the demands of flood control, of reservoirs, of power development, of navigation, and fish and wildlife management could be met with reasonable success. The conflicting interests of those seeking power, recreation, irrigation and flood control from a common stream call for ability to manage that all-important stream edge.

Factors finding expression in stream bank management are complex indeed. Water flowing steadily in and through an established irrigation ditch may do little damage, while other water moving with exactly the same speed over raw soil may be highly destructive. Water flowing over a hillside on which sod is well-established may do no damage whatever, while water flowing with equal speed down a similar hillside over unanchored soil may tear away useful earth and cover valuable land elsewhere with unwanted sediments. All of this makes the control of the waters' edge a challenging, interesting, and important problem to anyone.



Beaver

	DESCRIPTION	RANGE AND RELATIONSHIP
White Willow *Salix alba*	Shakespeare says: "There is a willow grows aslant a brook, that shows his hoar leaves in the glassy stream." This tree may be over 100 feet high, with a trunk diameter to over 6 feet. Alternate leaves to 4 inches long and ⅔-inch wide, dark green above and light beneath.	Native of Europe, but widely established in America. Seventy of more than 170 recognized species are found in America, thriving in moist, loose soil. Most closely related to crack willow or yellow willow. More than 20 species of trees. Family Salicaceae.
Kentucky Bluegrass *Poa pratensis*	"And I will give grass in thy fields for thy cattle, and thou shalt eat and be full," we read in *Deuteronomy;* and grass growing along stream banks helps keep water in its place. Tufted stems to 3-feet high. Flower-stem leaves to 6-inches long, ¼-inch wide, flat or folded, soft. Basal leaves larger.	Grasses include the cereals and much of the pasturage crops. In nature they are closely associated with, but not related to, the legumes, to form the sods that anchor soil. They provide porosity which admits water and air and improves productivity. Some 3,500 species over world. Family Gramineae.
Diatomaceous Oozes *Diatomaceae*	Rupert Brooke, in his poem "Heaven," tells us that fish look ahead and: ". . . somewhere, beyond Space and Time, is wetter water, slimier slime." He recognizes the importance of the aquatic slimes that give a dangerous but important slimy surface to most fixed, solid surfaces under water.	Diatoms are plants belonging to the Class Bacillarieae, essentially glass boxes containing plant material. With the valves symmetrical bilaterally in the Order Pennales, and circular or irregular in the Centrales. They occur in fresh, brackish, or salt water, and are usually mucus-imbedded.
Fresh-water Mussel *Lampsilis siliquoides*	Some stream margins may have muddy bottoms and slowly moving water. In these muds may burrow two-shelled mussels, or muckets. In this species, the two shells are about equal, 2 x 4 inches, hinged along straighter edge, greenish, with eccentric ridges, a single fleshy, spade-shaped foot.	This is a mollusk of the Class Pelecypoda and Family Unionidae, and is a fresh-water species. Some species may be found in compact muds of the bottoms of trout streams; others are limited to loose muds of pond-bottoms. Usually lie largely buried in the mud with access to freely moving water.
Fresh-water Shrimp *Gammarus fasciatus*	The plants that crowd the land in water at the edge of a stream often team with fresh-water shrimp that are to about ½-inch long, swim actively back-foremost, may be pale green, tan, or almost white, and may show a rather conspicuous eyespot and waving legs, antennae, and other parts.	The animal belongs to the Crustacea, which includes crayfish, crabs, and lobsters. Members of the Family Gammaridae live in fresh water, while others live in salt water. In the Amphipoda, the body is laterally compressed—as in these shrimps—while in Isopoda it is flattened from top.
Midges *Chironomidae*	Mud and stones at the edge of streams are frequently characterized by seeming "strings" of silt, which may actually be strings of silt-covered algae sheltering small, red "worms." These may be larvae of some of the midges that fly over water at certain seasons, and at various times.	These insects resemble minute mosquitoes, but have more delicate abdomens, legs and antennae, and are generally smaller. The veins and edges of the wings also lack the scaly fringes characteristic of such parts in mosquitoes. There are more than 200 kinds of midges in North America.
May Fly *Callibaetis sp.*	In 1778, Benjamin Franklin wrote an essay on *The Ephemera; An Emblem of Human Life.* Erroneously and facetiously, he assumed that May flies, members of the Ephemera, completed their life history in a day. The insects are delicate, hold wings erect over their backs and bear 2-3 "tails."	Some 100 species of May flies are known in the United States, and some 500 in the world. They hold their forelegs conspicuously forward, have abdomens that curve upward to rear as adults, and usually functionless mouth parts. Nymphs are aquatic, with abdominal gills and 2-3 "tails."
Stone Fly *Perla sp.*	Stone flies include more than 3,000 species of insects, mostly residents of waterways that do not become dry. An early species, *Capula pygmaea,* may appear in dark swarms over snow. Some later species in genus *Perla* are slow fliers; are sought by trout as food, by men as bait. Nymphs are aquatic.	Adults are to be found flying over streams, or in abundance on vegetation near streams during the breeding season. The nymphs cling to stones underwater, where they crawl about, seeking animal food. The adults may have non-functional mouth parts, or may have active, chewing mouth parts.
Brook Trout *Salvelinus fontinalis*	Tennyson characterizes a brook as having: ". . . here and there a lusty trout and here and there a grayling." The beauty of a brook trout can hardly be equaled—certainly by nothing whose realm is the edge of a stream. Weight to 17 pounds. Tail square-tipped. Back with wormlike markings.	Native from Labrador to Georgia, and to Montana and Saskatchewan in waters not exceeding 75° F. Now has world-wide distribution, and is becoming popular in farm fishponds. It may be crossed with brown or with lake trout, producing hybrids.

REPRODUCTION	ECOLOGY	ECONOMY
Flowers borne in spring on short lateral branches, as catkins whose yellow fruits burst, freeing fluffy seeds. Catkins seem weak, but do not ordinarily droop. White willow crosses freely with crack and shining willows. Commonly propagated through cuttings of twigs thrust into ground.	Wood is tough, takes high polish, is light brown, catches fire easily but does not produce a lasting fire. Branches may break and produce abundance of trash. Roots penetrate long distances for water and may invade and clog sewers. Wood used in artificial limbs and to make charcoal.	Role of tree in anchoring soil along banks of streams is widely recognized, and it is a common practice in stream management to thrust young shoots into ground along stream bank to establish and anchor soil, and to retard wasteful erosion. The bark is rich in tannin, and is used in tanning.
Flowers and fruits borne in open, pyramidal, terminal clusters, with the lower coming from a whorl of 5 branches. Spikelets of 3 to 5 flowers are to ¼-inch long. Grain enclosed in 2 scales, each to 1/10-inch long, longer than Canada bluegrass. Seed weighs 24 pounds to the bushel.	Grown alone, may yield to 900 pounds of valuable forage per acre. Wild white clover alone yields to 3,000 pounds per acre, but the two grown together may yield more than 5,000 pounds of more nutritious forage. Is perennial, and has dense root system forming durable compact sod.	A sod anchor at a stream edge is important in erosion control, to limit silt pollution, and to maintain fertility, which improves the quality of stream water for use by animals, including man. Bluegrass is a representative of a great group of plants that play an important role in economy of man.
There is vegetative, asexual and sexual reproduction, and the wavy strings seen attached to stones submerged in streams are often these plants. At death of the plants the organic material may decay, but the silica "boxes" may persist. May reproduce about every 5 days under good conditions.	An uninhibited diatom might yield in a year, through its descendants, about 60 tons of material. A bed off the California coast is ½-mile thick. In a short time a bed nearly 6 inches thick and to 20 miles long formed off Washington coast. Over 10 million square miles of sea bottom are diatomaceous.	Diatoms pollute and purify water. They are an important item of fish food. From the resultant earths, man makes polishing powders, explosives, tooth pastes, soap, waterglass and fireproof packings. In many ways diatoms are essential to our way of life, both directly or indirectly.
Males free sperms into water. These fertilize the eggs, which lodge in gills of female and may develop there from August to May. Young larvae are freed into water and become attached to bass. They develop on the bass for about 20 days, then leave and in 2 years may develop to 2-inch maturity.	Primarily scavengers, living on organic substances in the water taken into the clam body. Different species of fresh-water mussels may use different species of fish as hosts on which to develop as larvae. Major movements of the animals are effected during periods spent on the host fishes.	May serve as a water purifier, or as an index of purity of the water. Many rivers and streams have spectacular shoals that support large mussel populations, giving names like "Muscle Shoals" to such sites. Shells have minor value, and some fresh-water clams may support pearls.
Sexes mate from April to November, and may lay an average of 22 eggs every 11 days, incubating them for about 11 days. The young are then freed to mature in about 39 days. Sexes may remain clasped for long periods. Breeding not normal at temperature below 64° F.	Apparently can see well, and has good sense of touch. Protection effected largely by escape and by hiding in cover, and also by great reproductive capacity. Food is almost anything organic, including own kind. Animals may frequenly serve as efficient scavengers.	A basic organism useful in changing plants and small animals into a superior food for the larger animals of the waterways, and particularly for young fishes like trout, which may gorge themselves on fresh-water shrimps. Are too small to be used as bait; but all large fish start as small fish!
In one species of midge, the female lays a mass of some 700 brown eggs in water. In 3-4 days, these hatch into larvae that feed on microorganisms in the water for up to 2 months and develop as "red worms," usually covered by masses of silt-covered material. They finally come to surface as adults.	Most midges are harmless, but sometimes annoying in their abundance. Some, like the "punkies" (*Culicoides*) bite, and may be most troublesome at certain times of the year. All, however, serve as a basic food for many sport and food fishes, so have a certain economic value.	The evaluation of midges calls for information, restraint and intelligence. They may be intensely interesting, as when enormous swarms emerge to produce a humming sound or even a dark, dancing cloud. Basically, they convert minute water plants into a superior fish food.
Adults live only a short while, mating in flight. Female may lay to 1,000 eggs, dropping them or placing them underwater. In 6 weeks to 3 years nymphs hatched from eggs develop through as many as 21 molts to complete a generation. May be molt in adult stage, but no true pupal stage.	Aquatic nymphs bear repsonsibility for most of animal's life history as far as time is concerned. They may be free-swimming, mud-burrowers, or may crawl over submerged supports, feeding mostly on plant materials, which are chewed. Some may be carnivorous, but these are rare.	Role played is primarily that of converting aquatic plant material quickly into animal matter of food value to predatory aquatic animals such as fish. Unfortunately, because of nuptial flight, may not easily be confined for rearing under managed programs. Adults and nymphs may be abundant.
Adults mate soon after emerging from nymph stage, which lives in the water. Females lay eggs in masses of 200-300 in the water, with one female laying several thousand eggs. Eggs hatch in water into nymphs that crawl about on rocks under water, possibly requiring to 3 years to reach maturity.	Probably feed almost wholly on small aquatic animals that cling to rocks under water. May make a living from such animals as cling to undersides of submerged rocks in flowing water. Adults may eat nothing and die soon after breeding. Serve important role as food for fishes of swift water.	One species found in the West, *Tenipteryx pacifica*, may become serious pest in orchards, causing damage to buds of fruit trees. Presence of stone flies in a stream may be evidence that stream is permanent through the year. Fishermen capture adults downstream, use them effectively upstream.
Female builds nest in riffle over gravel, usually in fall, mates and lays to 5,000 eggs that mix with gravel; may be guarded to 3 weeks. At 50° F., eggs may hatch in 44 days, reach maturity in 1-2 years. Clutch of eggs may be to 80 per cent fertile. Water temperature most important in survival.	Food is largely small aquatic animals, but may be taken on artificial lures resembling nothing in nature. Cannot survive heavy pollution, and nests may be destroyed by rival fishes. Man is the most important factor in elimination or survival. The oxygen content of water must be high.	Possibly the best of all game fishes, producing unsurpassed food for man as well as superior sport. Lends self well to management techniques. Thrives at water's edge under sods undercut by current, or in root systems of trees undercut by streams. The ultimate in stream bank sport fish.

	DESCRIPTION	RANGE AND RELATIONSHIP
Horned Dace *Semotilus atromaculatus*	Length to less than 10 inches, but to boy beginning a fishing career this is unimportant. Here is a fish that will bite readily, fight for freedom, and generally meet minimum needs of a boy fisherman! Scales crowded forward of the dorsal fin. Sides and belly silvery. Breeding male blue above.	Common in small streams from Maine to Wyoming, to New Mexico and Alabama. It is also known as Creek Chub. May be associated with brook trout, common suckers and blacknose dace. Usually found in headwaters, streams, or in pools of larger streams reduced by drought. Family Cyprinidae.
Two-lined Salamander *Eurycea bislineata*	Wet little world between the stones at edge of a cool brook is ideal for this slender salamander. Length to 4 inches. Tongue attached at center beneath, but free at front margin. Pale straw-colored, with narrow, dark line down each side to the tail. Skin moist. Belly yellow. Sides dotted.	From New England to Florida and west to Louisiana and Lake Superior; related and similar species extend range slightly. Nine similar species in area. May winter under trash on land, or in deeper water than in summer. Family Plethodontidae. Order Caudata. Class Amphibia.
Water Ouzel, Dipper *Cinclus mexicanus*	Any bird that can match a water ouzel in walking under a swiftly-flowing stream and leaping from rock to rock in a torrent is entitled to an exultant song! Length to 8⅘ inches. Tail to just over 2 inches. Weight to 2⅓ ounces. Slate gray, paler beneath. Brown on tail and wings.	Breeds from near tree limit in northwestern Alaska to central-western Alberta, and south to southern California and southern New Mexico, with allied race in Mexico and Guatemala. Family Cinclidae is close to that of the wrens—the Troglodytidae—and to the wren tits, Family Chamaeidae.
Belted Kingfisher *Megaceryle alcyon*	A loud, rattling call, a flash of blue and white along the edge of a trout stream, and a bird may suddenly disappear into a hole in the stream bank. This chain of events may point to the belted kingfisher, whose length is to 14¾ inches, wingspread to 23 inches, and a weight of to 6 ounces.	There are 2 subspecies, the eastern and the western, collectively breeding from Alaska to Newfoundland and south to the Mexican and Gulf of Mexico borders. Winter range may extend to northern South America, including British Guiana, Trinidad and Colombia. Has been seen in Europe.
Phoebe *Sayornis phoebe*	A cliff along a little gorge with a stream, or a bridge over a stream without one or more moss-covered nests would be an incomplete picture and not typical. It is true that phoebes may live far from water, but they are significant in a stream-bank picture. To 7¼ inches long, tail to 3½ inches.	Breed from Prince Edward Island to central Mackenzie, and south to northeastern New Mexico and the mountains of Georgia. Winter in United States south of 37°, and on to Veracruz, Mexico. Three species in the genus recognized in the United States. A flycatcher. Family Tyrannidae.
Mink *Mustela vison*	"This little mink is fierce and sly, and steals around with cunning eye." Length to 28 inches, including an 8-inch tail. Weight to 3½ pounds, with females ¾ weight of the males, or less. Teeth, 1 3/3; C 1/1. P–3/3, M–1/2. Tracks, F–1½ x 1½; H–1½ x 1½; Sp–5; L–24, often with tail drag.	Range through most of North America except extreme North, the Southwest and Mexico, favoring stream banks; may be found some distance from streams but ordinarily cannot be considered as a desert or mountaintop animal. Related to weasel, badger, skunk, otter. Family Mustelidae.
Beaver *Castor canadensis*	"In mountain stream so clear and cool the beaver builds a swimming pool. He gnaws down trees to make them fall across the stream to form a wall." Length to 43 inches, including 16-inch naked, paddle-like tail. Weight to over 60 pounds. Teeth, 11/1; C–0/0; P–1/1; M–3/3. Webbed hindfeet.	Originally ranged through Canada and Alaska to Florida and Mexican border. Once nearly wiped out over much of range; now recovering through protection. Family Castoridae, but not in same family as mice and rats, or in same order as rabbits. Not limited to New World, rare in Old.
Stream Water *Water plus Pollutants, Oxygen and Motion*	Elements of a stream bank include the water, the earth over which it flows, and the plants and animals that live in or closely associated with either of above as a part of the bank society. We are not concerned here with tidal waters or with stagnant water but with waters that move non-cyclically.	In periods of flood and drought there may be variations in volume of water, its velocity, its turbidity, and its load of foreign matter, with resultant variations in effect on adjacent soils and on associated living things. All these variations leave records of significance, which may be read.
Stream Beds *Stream Beds Include Fixed Organic and Inorganic Materials*	Stream beds are rarely completely fixed, as portions erode due to the movement of water and of the load it carries. A load of eroded materials may increase the abrasive nature of the moving stream, or it may settle as sediment and change the velocity and direction of the stream.	Carved stream beds provide variations in water speed and depth, and provide variations like riffles, pools and shallows, which contribute to providing food, shelter, escape, anchorage to the organic part of stream society. Stream fish require variations in depth of water for livelihood.

REPRODUCTION	ECOLOGY	ECONOMY
Males build nests in riffles, removing silt from an area and making a pebble-lined, circular pit, with pebbles upstream. One or more females may mate with male, lay eggs, and leave male to guard them. Young may reach 1½-inch length in 5 months and 4 inches in 2 years.	Feeds mostly on small aquatic animals, taking a fly or a baited hook readily. Often become pests as bait robbers, raiding hooks offered associated game fishes. May support a large number of external parasites. Are eaten readily by larger fishes, and are thus imortant ecologically.	Good, hardy bait minnow and good food fish for the larger game species of their habitat. Flesh of horned dace is edible, but bones are a bit too abundant. Breeding fish can be stripped of eggs successfully, and fish may be reared in breeding ponds to sell as bait for pike and common panfish.
Elaborate fall courtship ends when male deposits a jelly-like spermatophore that female picks up. In spring lays eggs under swift water. May lay to 30 eggs, each ⅓-inch in diameter. Hatch in 10 weeks into slender larvae. Young reach length of 2 inches in 2 years before transforming into adults.	Food essentially small animals like worms, insects, crustacea, usually caught by foraging in daylight in water. May be most active and successful in escape behavior, changing quickly from quiescence to active scrambling. Some salamanders of area may be colon bacteria reservoirs.	Usually of only minor importance to man, but do serve role of controlling multiplication of small animals of habitat, and to a minor extent as food for some predators of area. Many salamander species haunt stream banks, and are interesting denizens.
Nests on ledge in gorge or canyon, close to—or even under—a waterfall; on rocks in midstream, or on beams under bridges. Nest is bulky, roofed, with a side entrance; made of plant materials, with a dry inner nest of fine material. Eggs white, 3-5. Incubation period is about 15 days.	Food largely aquatic animals like insects and even fish, including black fly larvae, caddis fly larvae gleaned from wet rocks in or under water. Birds can walk or swim through rapidly-flowing water even when the air temperature is under 50° F. below zero. Favors swift water.	Expresses the wild free spirit of water dashing through a canyon more than any other resident of the meeting place of land and water. Its marvelously loud and pleasant song is in keeping with the setting in which the dipper chooses to live. The bird is described well by many writers.
No nest is made, but eggs are laid at end of burrow, which may be 4 inches in diameter and extend to 15 feet into bank of soft earth, to end in enlarged room. Eggs 5-14, glossy white, incubated for 16-17 days, mostly by female; occasionally by male. In North, 1 annual brood; in South, 2.	Food is chiefly fish, but known to eat crayfish, frogs, mice, insects, and lizards. Food may include useful fish species, but generally speaking the birds are considered useful, and unless haunting a fish hatchery deserve the protection given them by the law. May fly up to 36 miles an hour.	Kingfishers may make changes in our stream banks, and consideration of their general role in nature may mold our ability to judge units of nature. We are losing many of our more attractive birds, possibly because of poison campaigns. Let it be hoped that we never lose our last kingfisher.
Nest built in a crevice on a glen wall, under a bridge or porch, or in an old building or other shelter, usually of mud with a grassy or mossy covering. Eggs 3-8, usually unspotted, or with a few scattered spots. Incubation by one or both sexes, for 12-16 days. Annual broods, 2-3.	Food almost exclusively insects, usually caught on the wing. Careful surveys indicate that nearly all food taken includes insects and other invertebrates harmful to man's interests, such as crickets, grasshoppers, ants, cucumber beetles, ticks, moths, beetles.	Habit of nesting about old country homes endears these birds to many. Audubon banded some of these birds and studied their return habits long before bird banding was popular hobby and research technique. Call something like courting call of chickadee; may be confused with latter.
Males mate with more than one female, February to March, but stay with one until 3-8 young are born in 45-60 days. Young blind to 5 weeks, weaned at 5 weeks, and leave den at 6-8 weeks. Breed at 1 year and, protected, may live for 10 years or more.	Food is muskrats, birds, frogs, snakes, fish; in winter may pursue, catch and kill cottontails on land. Home range of nursing mother is about twenty acres. Males range over much larger area. May raid poultry houses, killing more than are eaten. Den is in hollow log or cave in streambank.	"His fur is soft and brown and sleek, and twenty trappers worked a week before they gathered skins enough to make your grandma's cloak and muff." Fur durability is 70 per cent that of otter. Many pelts now raised on mink farms, where quality may be developed by controlling ancestry.
Apparently pair for life. Breed January-February, and 2-8 young born in 65-128 days. Seek solid food at 1 month. Cease nursing at 6 weeks. Weight to 8 pounds by midsummer. Mature in 2-3 years. Family is usually basis of a colony, with 2-year-olds driven from old home to start anew.	Food is solely plant material, largely bark, stored underwater for winter use. Den at end of burrow into bank, or in a house built with entrance below iceline permitting year round access. In house, roof freezes, preventing entrance of enemies. Build dams that frequently control water level.	Dams form ponds that collect sediments and form basis of rich agricultural lands. May flood forested areas, and may destroy orchards and timber trees by flooding or by cutting. Pelts are valuable, and formed basis for much of America's original prosperity and early development.
Movement of stream water largely determines nature of associated organisms, some of which move with stream while others—by streamlining or by individual effort—use moving water to bring them food, remove wastes, and provide variations needed by animals to go through life cycle.	The ability of water to dissolve associated substances affects the stream bank phenomenally and frequently wears away rocks selectively, producing variations that cause change in stream direction and velocity. The dissolved materials affect the plants and animals living in stream.	Temperatures of streams vary partly because of color of rocks in stream beds, partly because of temperature of air mixed with the water in a swiftly moving stream. Temperatures determine both oxygen content of many streams and the plant and animal populations to be found in them.
Stream beds may be scoured by flood waters, by ice particles in the water, by moving silts that erode plants from stone surfaces and change entire stream economy. However, stream bed is rarely uniform either vertically or horizontally; with rest, original status may be regained.	Physical geography tells enchanting stories of the origin and development of stream systems, and of the records they leave behind them when streams change their courses. Streams abandon portions of their courses, join with other streams, and produce interesting new biologic associations.	Just as phenomenal developments take place at borders of woodlands and fields, so the most fruitful area of a waterway may be the place where it meets confining land, and where the give and take of calm and violence, and other variants, create conditions for a variety of developments.

nature IN THE SCHOOL

In the springtime, the edges of streams draw youngsters as surely and certainly as a horseshoe magnet attracts bits of iron. Indeed, there are towns in this country where the local merchants give certificates to children who agree to stay away from stream banks during the time of spring high water—certificates that are redeemable in ice-cream cones when the danger season has passed. The merchants feel well rewarded in their contribution to preventing spring accidents, which are all too prevalent along the nation's waterways.

For the purpose of the schoolroom, there are three major questions involved in the study of stream edges. First, what happens at the edges of a stream? Secondly, why does it happen? And lastly, what can be done to make it happen? Certain stream bank events take place quickly—perhaps in a matter of a few seconds. Other events are measured in much longer units of time. But the time element concerned in any particular event is not as important as the sequence of its component parts; for study purposes, the question is: what may be expected to happen next? Is there a definite pattern?

A stream of water flowing along a slushy street gutter in spring may offer some significant lessons for youngsters who like to experiment with dams, channels, diversion ditches, and waterfalls. In such miniature streams the movement of slush may be suggestive of the movement of silt in the larger-scale stream or river; and a description of the events that take place may be made by a young student with a reasonable degree of accuracy.

With the help of the suggestions given in the text of this insert, students may learn how to determine the volume of water that passes a given point in a stream during time of flood. They may learn to estimate the speed of a stream by observing the effect of the moving water on earthy units moving along the stream bottom. They may observe that fragments of ice, breaking free from a stream bank, may carry away larger or smaller portions of soil as they move away. The student may notice, too, how the water in a plunge basin below a waterfall tends to widen the stream at that point, and how, as the speed of the stream diminishes, its load of silt or other material drops to the bottom, perhaps to eventually change the course of the stream.

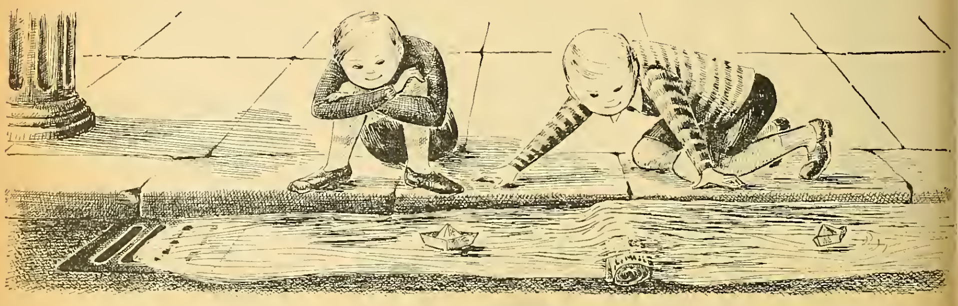
It might be worth while, in this connection, for the student to map the course of a stream of water through a snow dam, and to clarify the resulting graphic description with a series of pictures showing how the stream course changes, and why.

Holes that may occur in the banks or bottoms of streams are always significant, and they may be studied, mapped, and perhaps explained. Young trappers may learn something of the habits of the animals they seek to capture by learning to identify the tracks, trails, and other signs animals leave behind them, such as scraps of gnawed food, droppings, dens, or signs of conflict.

It might also prove interesting to map the side of a stream through a given distance to indicate the location of all observable birds' nests; the usual routes followed by the birds in flying up or downstream; the sites where the birds sing most frequently; and the territories defended by nesting pairs of birds that use the stream bank as a homesite. It should be noted that some species of birds nesting in or along stream banks seem to enjoy the company of other birds of their own kind; while other species are solitary in their habits.

The student may be able to form an opinion as to such differences of habit by observing the extent of the territory each bird visits in its search for food. Involved here is the relative ability of the different bird species to cover considerable distances with ease. A spotted sandpiper, for example, cannot move with the ease of a cliff swallow, and the two have different communal habits. What suggestions for an explanation do these facts suggest?

The great lessons to be derived from a study of stream edges are primarily associated with the gain and loss of soil along margins. However, any study of the stream bank would not be complete without a mention of stream improvement. How may the banks of a stream be improved? How may the production of food plants—and the small animals that feed the larger animals of the stream—be improved? How may the stream be prevented from adding to the silt pollution and flooding problems? Streams are dynamic and changeable—but they may be managed. A start in understanding them must be made at the school level—and it could well prove to be a most enjoyable subject.



Street gutter can be valuable site for study of silt movement.

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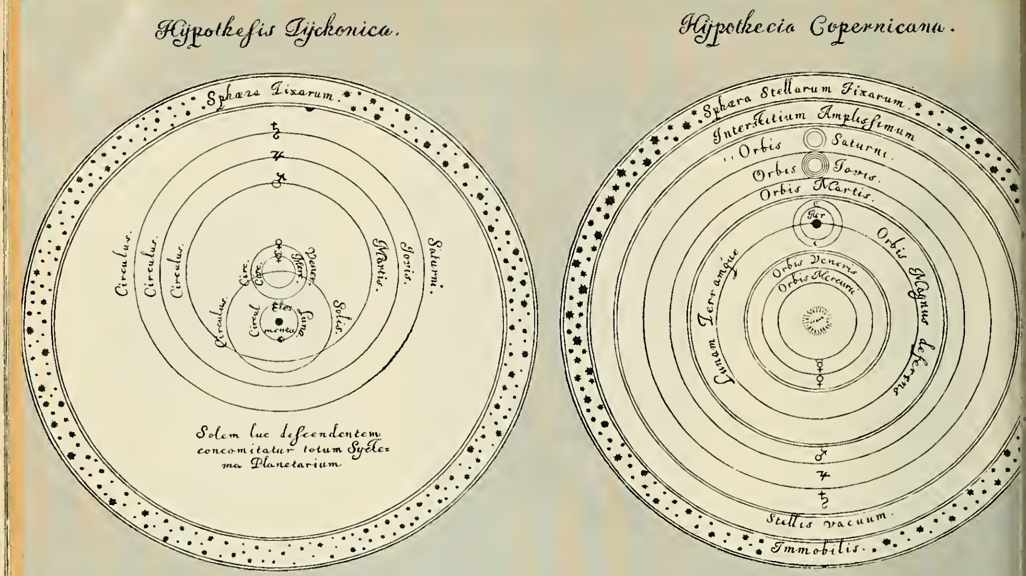

Hypotheſis Tychonica.
Hypotheſis Copernicana.
Sphæra Fixarum.
Circulus
Circulus
Circulus
Saturni.
Jovis.
Martis.
Solis.
Veneris.
Lunæ
Circul
Terra
Solem luc deſcendentem concomitatur totum Syſtema Planetarium
Sphæra Stellarum Fixarum.
Interſtitium Ampliſſimum
Orbis Saturni.
Orbis Jovis.
Orbis Martis.
Ter
Orbis Veneris
Orbis Mercurii
Orbis Magnus deferens
Lunam Terramque
Stellis vacuum.
Immobilis.

Tycho Brahe modified the heliocentric theory of Nicolaus Copernicus, mistakenly restoring the earth to the center of the universe, *right*. Diagrams of both systems are shown a they appear in J. Hevelius' *Selenographia* (Dantzig, 1647

SKY REPORTER

Nicolaus Copernicus an the heliocentric theor

By Simone Daro Gossner

It would be wrong to assume that the scientists and philosophers of the Middle Ages and the Renaissance had embraced Ptolemaic theories without reservation. Aristotle—whose principles were the backbone of medieval science—had spoken of perfect celestial bodies moving at constant speed along circular orbits centered on the earth. There was a fundamental conflict between such notions and the Ptolemaic concepts of epicycles and eccentrics, in which bodies were assumed to move around the earth at varying speeds in off-center orbits. Die-hard Aristotelians resolved this dilemma, however reluctantly, by considering Ptolemy's theories as a convenient mathematical hypothesis, suitable for the prediction of celestial phenomena, but without true physical meaning.

By the time these theories gained general acceptance (*ca.* A.D. 1400), however, they no longer provided the degree of accuracy required by astronomical observations of the period. Skilled modifications at the hand of fifteenth-century astronomers Purbach and Regiomontanus gave them renewed impetus, but a few of the more liberal thinkers soon began to cast about for other means of solving the problem of planetary motions. One of these men was destined to propose a system which, in its day, led to one of the most impassioned scientific controversies of all times.

Niklas Koppernigk, who later latinized his name to Nicolaus Copernicus, was born in Torun, Poland, on February 19, 1473. The youngest son of a magistrate, he was orphaned at the age of ten and was adopted by his maternal uncle Lucas Watzenrode who soon thereafter becam Bishop of Ermland (Prussia). His uncle's intention prepare him for a lay position within the church governe his education. His studies bore the imprint of an era i which the classics had been newly rediscovered and a avenues of learning were eagerly followed.

The young Copernicus was schooled in law and medici as well as mathematics and astronomy. The decisive tu in his career seems to have occurred during his close ass ciation, at the University of Bologna, with the Italia astronomer Domenico Maria da Novara. He participate in Novara's observations and shared his growing dissati faction with ancient planetary theories. It is probable th Copernicus began elaborating his new system shortly aft his return to Poland in 1506. Although a preliminary ve sion of his treatise was circulated in manuscript form pe haps as early as 1512, he delayed its publication in fin form for fear of ecclesiastical censure. Edited by a fe trusted friends, *De revolutionibus orbium coelestium* (C the revolutions of celestial bodies) appeared in print the spring of 1543, while the author lay on his deathbe felled by a stroke in his seventy-first year.

The Copernican theory follows the Aristotelian traditi of circular orbits described at uniform speed, a retains the Ptolemaic hypothesis of epicycles and deferent But its importance to the history of cosmological thoug lies in that it rejects the notion of a universe centered on static earth. The theory supports this heliocentric sta with plausible arguments (in contrast to the short-live eliocentric theories of the ancient Greeks, which were ere exercises of the imagination).

All planets, including the earth, have deferents centered n the sun. The moon, hitherto classified as a planet, beomes a satellite of the earth. Rotation of the earth is ssumed in order to account for the apparent daily motion f the skies. The seasons are explained correctly as resulting rom a tilt of the earth's polar axis. Finally, all planets are laced in their proper sequence (*see* diagram at left, facing age), and Copernicus was able to determine from observaion their relative distances from the sun in terms of the arth's own distance from that central body.

Pre-Copernican theories assumed that the universe is in act quite small, with all visible stars attached to an outernost sphere scarcely beyond the orbit of Saturn. Having ostulated that the sun, rather than the earth, is the center f the universe, Copernicus was forced to give the sphere f the stars a considerably greater radius. Otherwise, the nnual motion of the earth around the sun would have esulted in a periodic displacement in the apparent posiions of the stars (larger displacements corresponding to horter distances). Since no such effect had yet been oberved, Copernicus had no choice but to expand the size f the universe. Ironically, such displacements *are* observed vith modern instruments—and prove the validity of helioentric theories—but they are too minute to have been neasurable with the equipment of the sixteenth century.

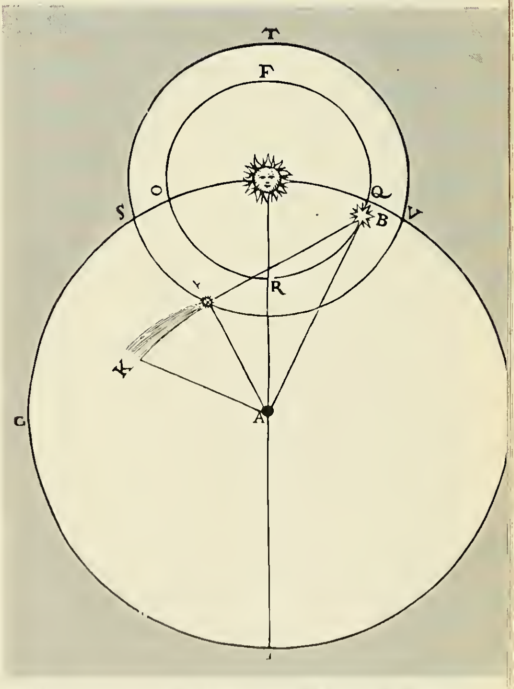
As it were, the size of Copernicus' sphere of stars was ne of the reasons why the Danish astronomer Tycho Brahe 1546-1601) would not accept the new system: he felt that here was no philosophical justification for such an imnense void between Saturn and the stars. In addition, rahe was a fastidious observer, equipped with the most recise instruments then available. He became intensely ware of the remaining inaccuracies in Copernicus' work nd undertook to develop a theory of his own.

The Tychonic system (*see* diagram at right, opposite age) was a hybrid between the traditional geocentricism f Ptolemy and the new heliocentric approach. The earth s returned to its privileged position at the center of the niverse, which may thus be shrunk back to a more "logial" size; the sun and moon revolve around the earth, but he remaining planets revolve around the sun, accompanyng the latter in its annual motion; the entire universe otates around the earth once every twenty-four hours. Vith the fine observations, which Brahe accumulated in his ifetime, there is no doubt that he could have developed his ystem into a working hypothesis far more precise, albeit nore artificial, than that of Copernicus. Because of his ntimely death, at the age of fifty-four, Brahe's proposed reatise remained unfinished.

WHEREAS Tycho Brahe's planetary theory was a compromise intended to uphold some Aristotelian priniples, his observations of natural phenomena, on the ontrary, did much to refute Aristotle's pronouncements bout the nature of celestial bodies. Although novae (stars hat suddenly flare up to many times their original brightess, only to fade away gradually) are not uncommon, rahe's detection of such a nova in the constellation of assiopeia, in 1572, was a novelty at that time. He observed t with care and proved its stellar nature, thus providing he first hint that stars are not the immutably perfect obects that Aristotle had believed them to be.

Brahe's discussion of the bright comet of 1577 proved equally remarkable. Until then, it had been assumed that comets were atmospheric phenomena. But having compared his observations obtained in Denmark with those of a colleague in Prague, Brahe found that the comet had been seen in the same direction at both places. Therefore he concluded that the object was, in fact, much farther away than the moon and was following a path around the sun that carried it beyond the orbit of Venus (as shown in his diagram, which is reproduced below).

ACCEPTANCE of the heliocentric theory was hindered by the philosophical climate of the sixteenth and seventeenth centuries. Aristotelians opposed it solely on the ground that Aristotle had taught otherwise. German and French Protestants were averse to it from the start because it conflicted with a literal interpretation of the Scriptures (the reaction in England was more favorable). The Catholic Church was fairly apathetic at first, but its attitude became adamant when the Italian philosopher Giordano Bruno (1548-1600) expanded the ideas of Copernicus and spoke of an unlimited universe with countless inhabited planets. Bruno was burned at the stake; the Edict of 1616 placed *De revolutionibus* on the Index "until corrected" and barred the teaching of heliocentric theories. Although the ban was not lifted officially until 1822, Copernicus' heliocentric views nonetheless gained wide acceptance in the scientific world by the end of the seventeenth century.



OBSERVATIONS of the comet of 1577 convinced Brahe that it was in orbit around the sun (from *Opera Omnia*, 1648).

THE SKY IN APRIL

From the Almanac:

Full Moon	April 1, 12:48 A.M., EST
Last Quarter	April 8, 5:16 A.M., EST
New Moon	April 15, 12:38 A.M., EST
First Quarter	April 22, 4:50 P.M., EST
Full Moon	April 30, 1:41 P.M., EST

For the visual observer:

Mercury should be viewed during the first few days of April if one wants to see it at all in the course of that month. It will be in the morning sky, rising 45 minutes before the sun on April 1, and 30 minutes before on April 15, but lost in the sun's glare by the end of April.

Venus, on the contrary, will be more favorably placed toward the end of April. Still in the evening sky at the beginning of the month, it will set about an hour after the sun on April 1 and may be seen low in the west at sundown for the next few days. It will be in inferior conjunction on April 10 and thus will enter the morning sky on that date. By the end of April, Venus will have brightened to −4.1 magnitude and will be seen rising in the east about an hour before the sun makes its dawn appearance.

Mars, in Gemini, will be about as bright as Pollux. It will be overhead after sunset on April 1 and will set in the northwest at 2:00 A.M. on that date, at 1:30 A.M. on April 15, and at 1:00 A.M. on April 30. The planet will pass south of Castor and Pollux at midmonth.

Jupiter, in Capricornus (−1.8 magnitude), will rise on the southeastern horizon at 3:00 A.M. on April 1, at 2:00 A.M. on April 15, and at 1:15 A.M. on April 30.

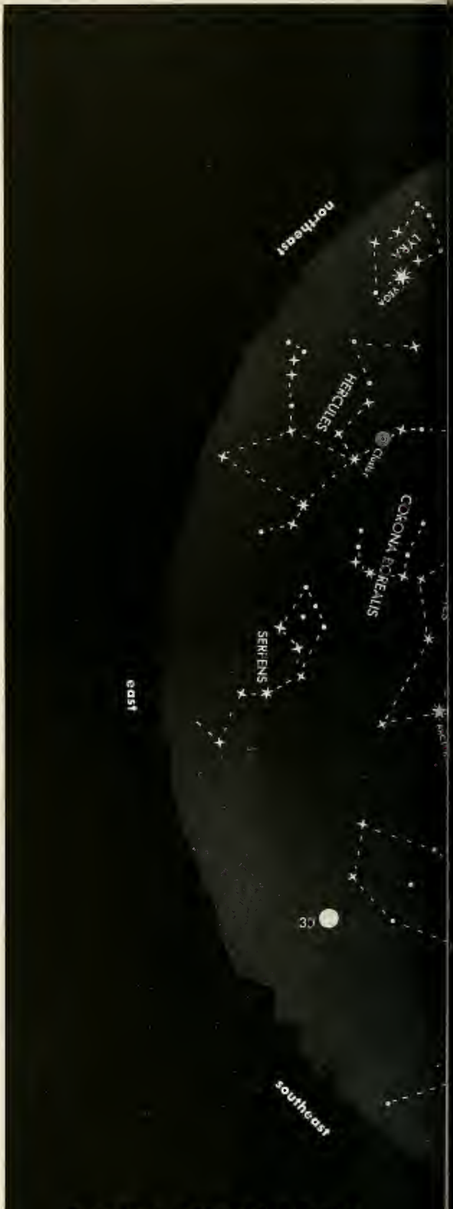
Saturn, also in Capricornus (+0.8 magnitude), will remain approximately 6° west of Jupiter, rising about 15 minutes before the latter throughout April.

The Lyrid meteor shower may be expected on April 23. The moon, at first quarter on the preceding day, should not reduce appreciably the number of visible meteors. This shower is somewhat less than spectacular, however, with a predicted rate of 6 per hour (for a single observer).

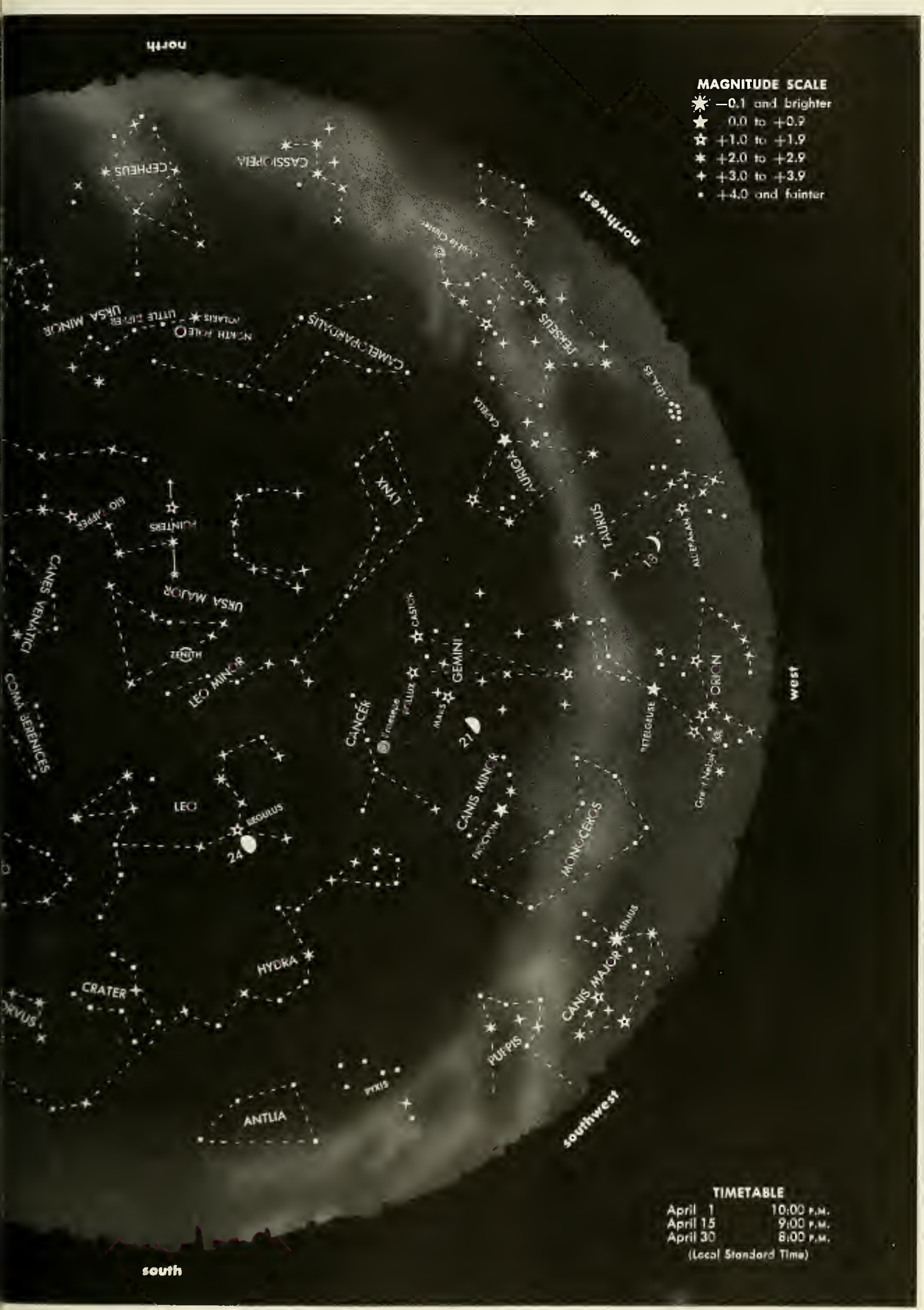
The signs of the zodiac:

Shortly before 400 B.C., Babylonian astronomers subdivided the ecliptic into twelve identical sections, each spanning 30°, for the purpose of facilitating their mathematical computations. These sections—or *signs*—were given the name of the zodiacal constellation that they contained. The first (Aries) began at the vernal equinox. In subsequent centuries, the signs of the zodiac were used extensively as a convenient means of describing the position of sun and planets along the ecliptic. As time went on, the slow change in the orientation of the earth's polar axis in space caused a steady displacement of the vernal equinox with respect to the zodiacal constellations. Today, almost 2,400 years after the Babylonians first subdivided the zodiac, this displacement amounts to nearly a whole constellation. The signs, however, have *not* been renamed, with the confusing result that the constellation of Pisces is in the sign of Aries, and so forth, around the zodiac. To avoid misunderstanding, the use of zodiacal signs has been discontinued in astronomy. Instead, the positions of planets are now given with respect to the constellations in which they appear.

On the preceding pages, MRS. GOSSNER offers the fourth in her 1961 series on the growth of cosmological concepts.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.


north
northwest
west
southwest
south
CEPHEUS
CASSIOPEIA
URSA MINOR
LITTLE DIPPER
POLARIS
NORTH POLE
CAMELOPARDALIS
Double Cluster
ALGOL
PERSEUS
PLEIADES
CAPELLA
AURIGA
LYNX
BIG DIPPER
POINTERS
URSA MAJOR
ZENITH
CANES VENATICI
COMA BERENICES
LEO MINOR
TAURUS
18
ALDEBARAN
CASTOR
POLLUX
GEMINI
MARS
21
CANCER
Praesepe
ORION
BETELGEUSE
Great Nebula
CANIS MINOR
PROCYON
MONOCEROS
LEO
REGULUS
24
HYDRA
CRATER
RVUS
SIRIUS
CANIS MAJOR
PUPPIS
PYXIS
ANTLIA

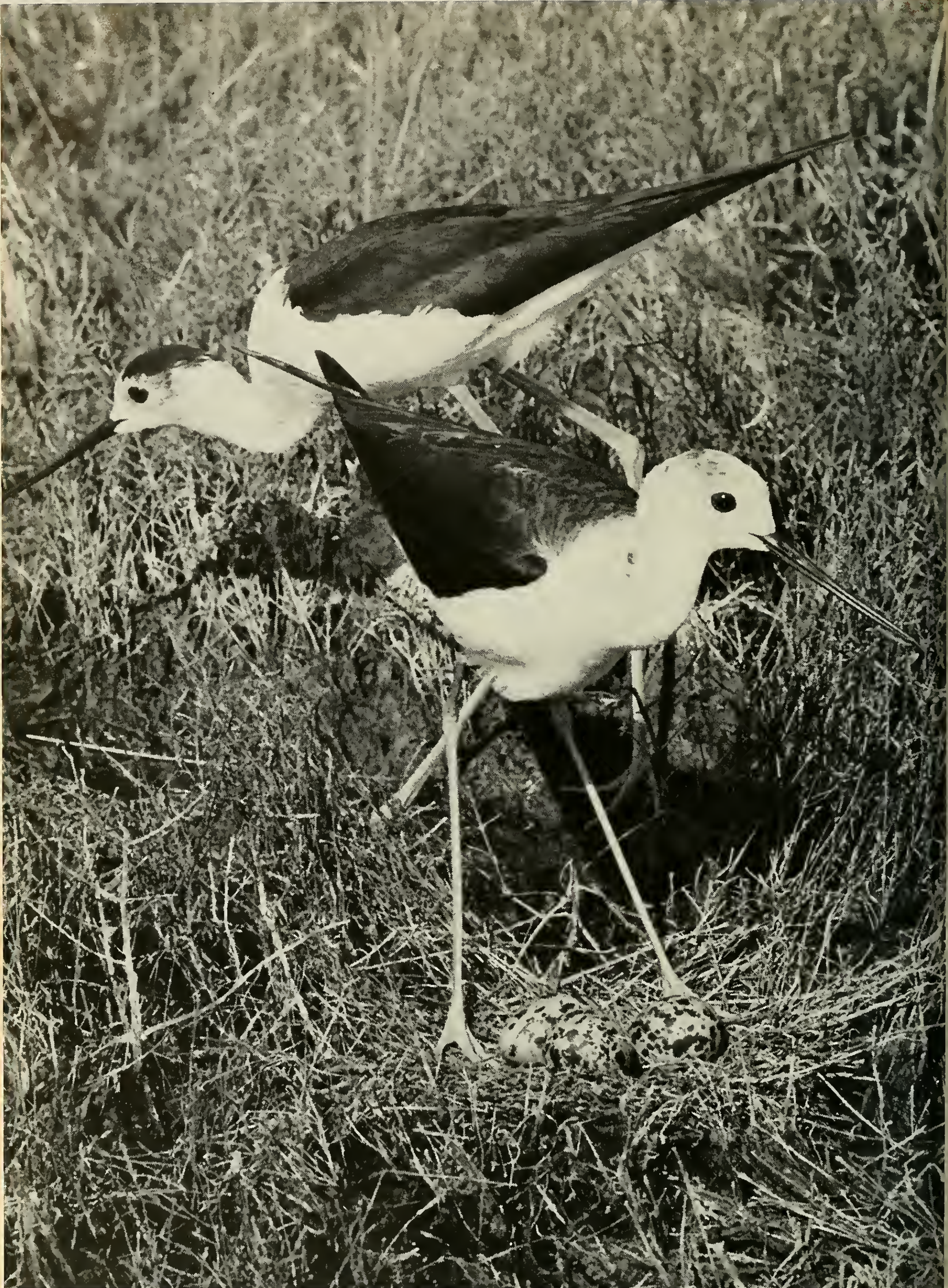
MAGNITUDE SCALE

✵	−0.1 and brighter
★	0.0 to +0.9
☆	+1.0 to +1.9
✱	+2.0 to +2.9
✦	+3.0 to +3.9
•	+4.0 and fainter

TIMETABLE

April 1	10:00 P.M.
April 15	9:00 P.M.
April 30	8:00 P.M.

(Local Standard Time)



Black-winged stilts, on their long, pink legs, alertly patrol the area around their nest with its speckled eggs. These were found near Lake Atanasovo on the Black Sea coast, an unlike other species, have increased in the last ten year

AKE **SREBURNA**'s reed beds are sites for explorations by British ornithologists searching for Dalmatian pelicans. Persecution by peasants and burning of reeds during last hundred years has critically reduced numbers of this bird.

A Survey of Bulgarian Birds

Ornithologists make first postwar study of the Balkan area

By GUY MOUNTFORT Photographs by ERIC HOSKING

THREE GREAT EUROPEAN RIVERS' deltas—those of the Rhone in rance, the Rio Guadalquivir in Spain nd the Danube in Bulgaria and Ru-nania—have become centers of great nterest to naturalists. All three pro-ide refuge and breeding grounds for ome of Europe's rarest birds, but the ressure of human needs, such as agri-ultural land reclamation by large-cale drainage projects, is threatening each of them. The animal and plant ecology of the famous Camargue sanctuary in the Rhone Delta has been extensively studied. So, to a lesser degree, has that of the Coto Doñana sanctuary at the mouth of the Guadalquivir. The delta of the Danube, however, has been inaccessible to detailed study for decades and little has been known about its wildlife.

Last year, thanks to the co-operation of the Bulgarian Committee for Cultural Relations with Foreign Countries and of the Academy of Sciences at Sofia, a British expedition of nine leading ornithologists was permitted to make the first postwar exploration of the south bank of the Danube, the adjacent Dobruja steppe, and the Black Sea coastal regions.

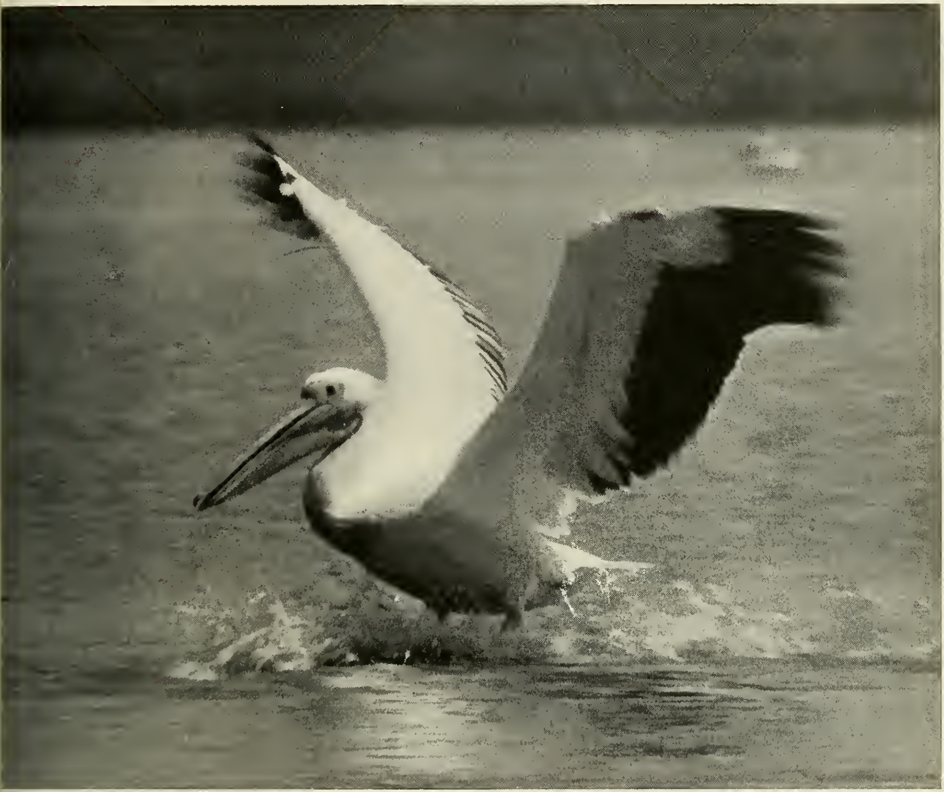
The first task was to locate the Dalmatian pelican and the white pelican—

Main breeding grounds of white pelicans are now on the Rumanian side of the Danube. This small group represents only a few of the seven hundred birds sighted on the Bulgarian side, on Lake Burgas. No nests were discovered.

two species that have long been famous among Bulgaria's birds. In 1868, the combined populations in the delta area were numbered at several million. Today, because of constant persecution by peasant fishermen and the extensive annual cutting or burning of the reed beds in which the great birds nest, the total is no more than 1,000 pairs, of which only 700 breed yearly.

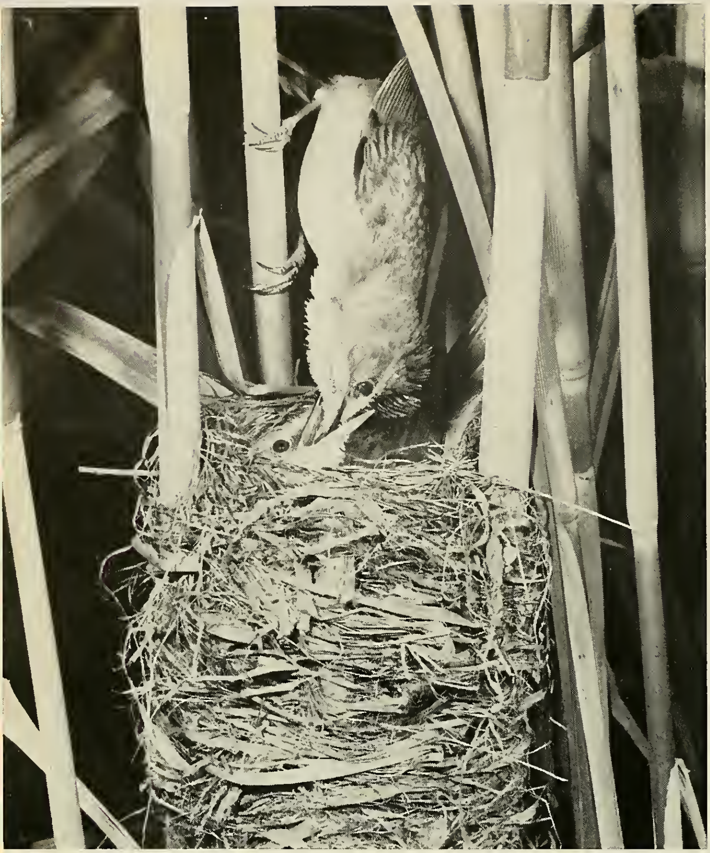
The Dalmatian pelican, the larger bird of the two, represents only a third of these totals, and is obviously in considerable danger of extermination as a European species. Small mixed colonies have been located on the Rumanian side of the Danube, but in Bulgaria only about thirty pairs still nest on Lake Sreburna. When the expedition reached this lake, we were horrified to find that all the nests had just been burned, with young birds in them. Lake Sreburna is listed as a wildlife sanctuary, but enforcement of the law is difficult in such a remote area, and the local peasants have no love of birds that eat fish.

The expedition therefore moved south down the beautiful Black Sea coast in search of the white pelican, 700 of which were eventually located and photographed on Lake Burgas. They were nearly all immature birds



Hundreds of the huge pelicans glide down on stiff wings o inspect the photographer's blind at lake's edge, *below.*

Black undersurfaces of white pelican's flight feathers, *above,* distinguish the species from the Dalmatian pelican.



Head-standing male great reed warbler feeds his mate as she incubates her eggs in their skillfully suspended nest.

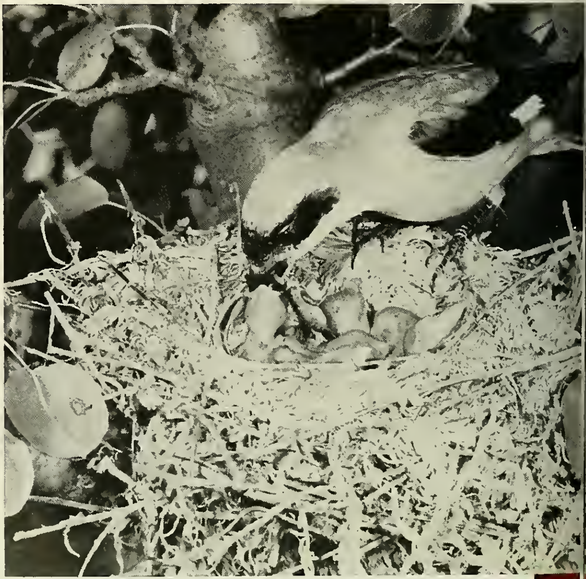
and no nests were found. The flock was too large to be the non-breeding part of the Rumanian bird population, and it seems probable that many must have come from the Russian breeding grounds in the Volga Delta.

The use of poison bait to kill wolves and jackals in Bulgaria has inevitably reduced to a critical level the numbers of carrion-eating birds, such as the bearded vulture and some of the carrion-eating eagles. Fortunately, other large birds of prey are still fairly numerous in remoter regions, and the British expedition was successful in finding and photographing a lesser spotted eagle at its nest. This fine bird occurs only in the Balkans and eastern Europe. The white spots on its dark plumage, from which it gets its name, are visible only in the immature birds. The nest that we located was in the center of a swamp forest. In the co of two weeks, working for one l each day, we gradually construct pylon over forty-five feet high ne the nest-tree, and a hide for the tographer was secured on top.

When all was ready, vio storms turned the region i quagmire. Next day, though it was raining, we reached the site, onl find that the newly hatched baby had been blown out of the nest! its forty-five foot fall, it lay on th ground, apparently dying and alr flyblown. However, after b warmed inside Eric Hosking's shi was revived and replaced in the Soon both parents returned to frogs and small mammals to the f ling, thus providing a fine seri pictures, the first ever obtained o handsome species.

Bird life is extremely varied i Black Sea coastal region. We f great reed warblers nesting colon around all the lakes, in addition t onies of various species of ducks, and terns. The strident chorus o warblers' songs vied with the yel cries of black-winged stilts, whic trolled the shallows on grotes long, pink legs, guarding their s led eggs on the muddy shores. A the country roads, handsome l gray shrikes and blue-and-che

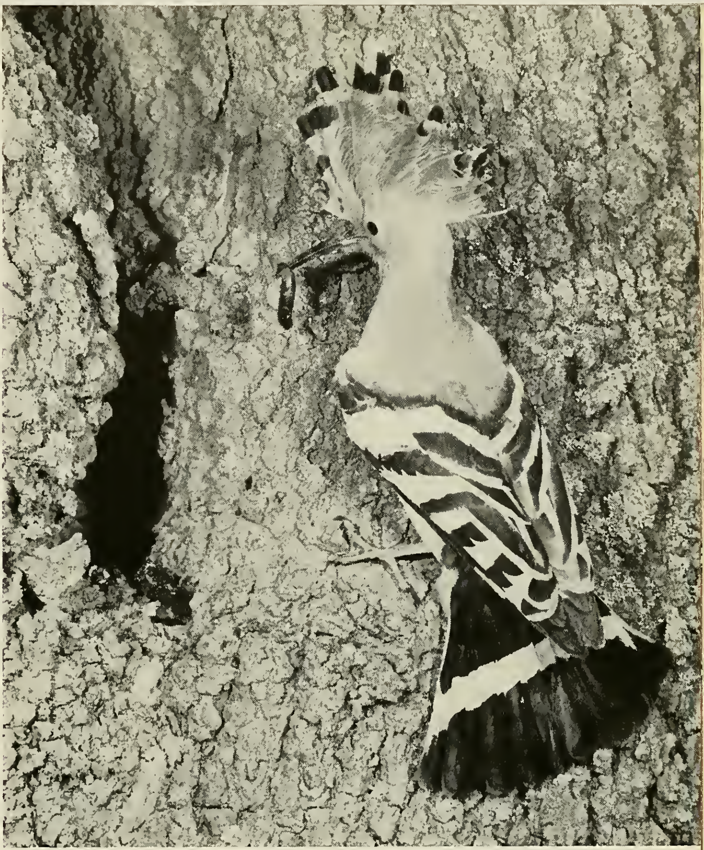
Lesser gray shrike, *below,* resembles loggerhead shri North America, but has a broader mask and a heavier



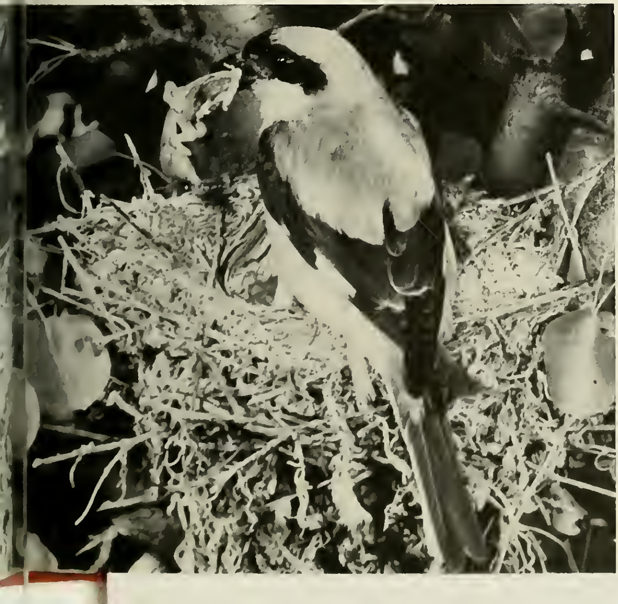
R. MOUNTFORT, an advertising man, also the secretary of the British rnithologists' Union. As England's remost photographer of birds, **MR. OSKING** has pursued his subjects to l parts of the world. His work has equently appeared in this magazine.

ers sat on the telegraph wires, ely to pounce on lizards or beetles th were then quickly carried to gry nestlings. Red-backed shrikes e so numerous in some localities th nests could be found in almost ry bush. Around the forest margins a the vineyards, the contralto "*poo*-*-poo*" of hoopoes and the ringing "*ela-weeoo*" of golden orioles could heard on all sides. White storks e nesting confidently in or around the villages, and there were flocks rilliantly colored bee eaters, goldhes, and rose-colored starlings.

HE expedition specifically sought evidence on the migration of birds g the Black Sea coast. Previously, ad been assumed that spring migras moved north along the coast and ce either across the Ukraine and the valleys of the Dniester, Bug, Dnieper rivers, or westward along Danube. The expedition found, ever, that while huge flocks of mints occurred in the region of the gas coastal lakes, scarcely any were to be seen north of there. It therefore appeared that, instead of continuing to follow the coast, the flocks turned west across Bulgaria along the southern flank of the great Balkan Range, followed the so-called "Balkan Corridor" valley, and thence moved northwards through Yugoslavia. This view had already been expressed by Mr. Anthony Lambert, the British Minister in Bulgaria, as the result of observations he had made in early spring, but an intensive study must be undertaken to verify the preliminary findings.

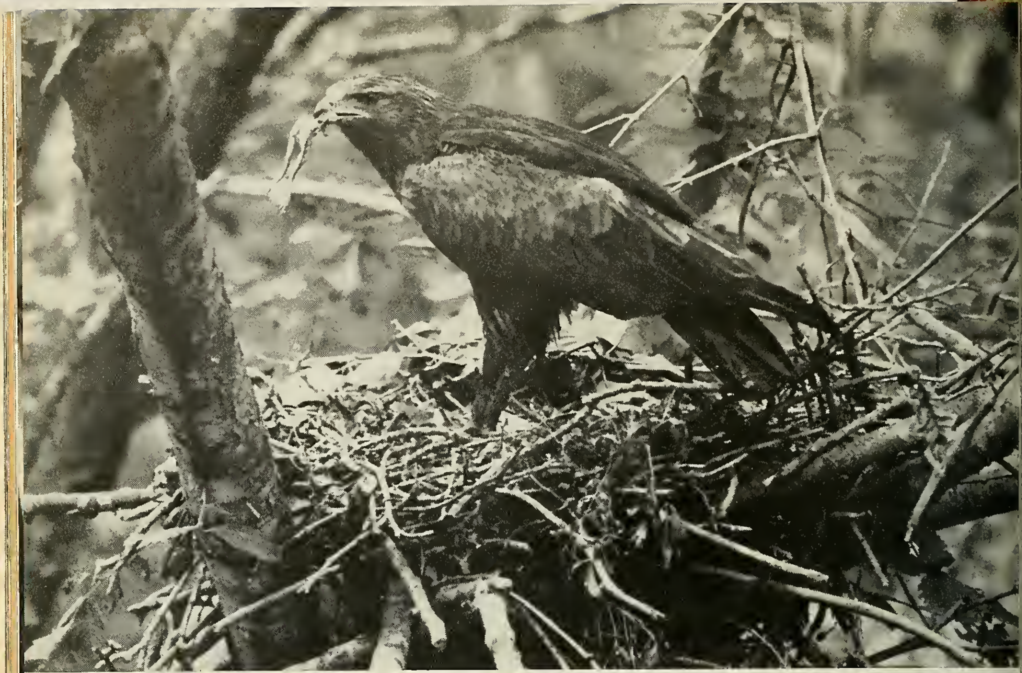


HOOPOE, *above*, black-tipped crest erect, perches briefly outside entrance to hole in dead tree that houses its nest.

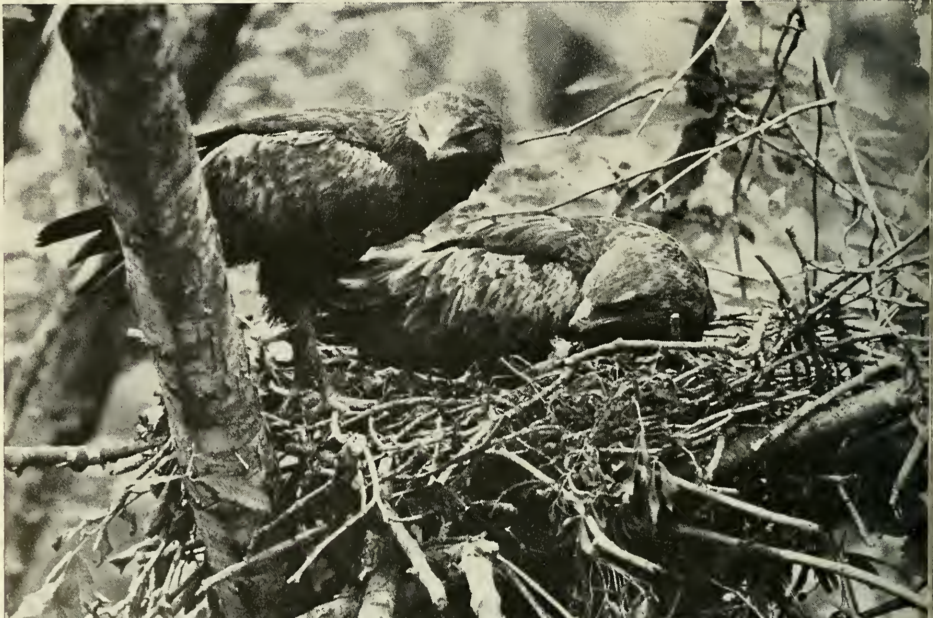


F **ALE SHRIKE** removes dead nestling from brood of six. ike bush-nesting shrikes, these build high in treetops.

ALTHOUGH Bulgaria has as yet no ornithological society and little amateur interest in the subject—indeed, it does not even have any illustrated textbooks on birds—there are indications that vigorous efforts will be made to preserve the exceptionally rich bird life remaining in the region.

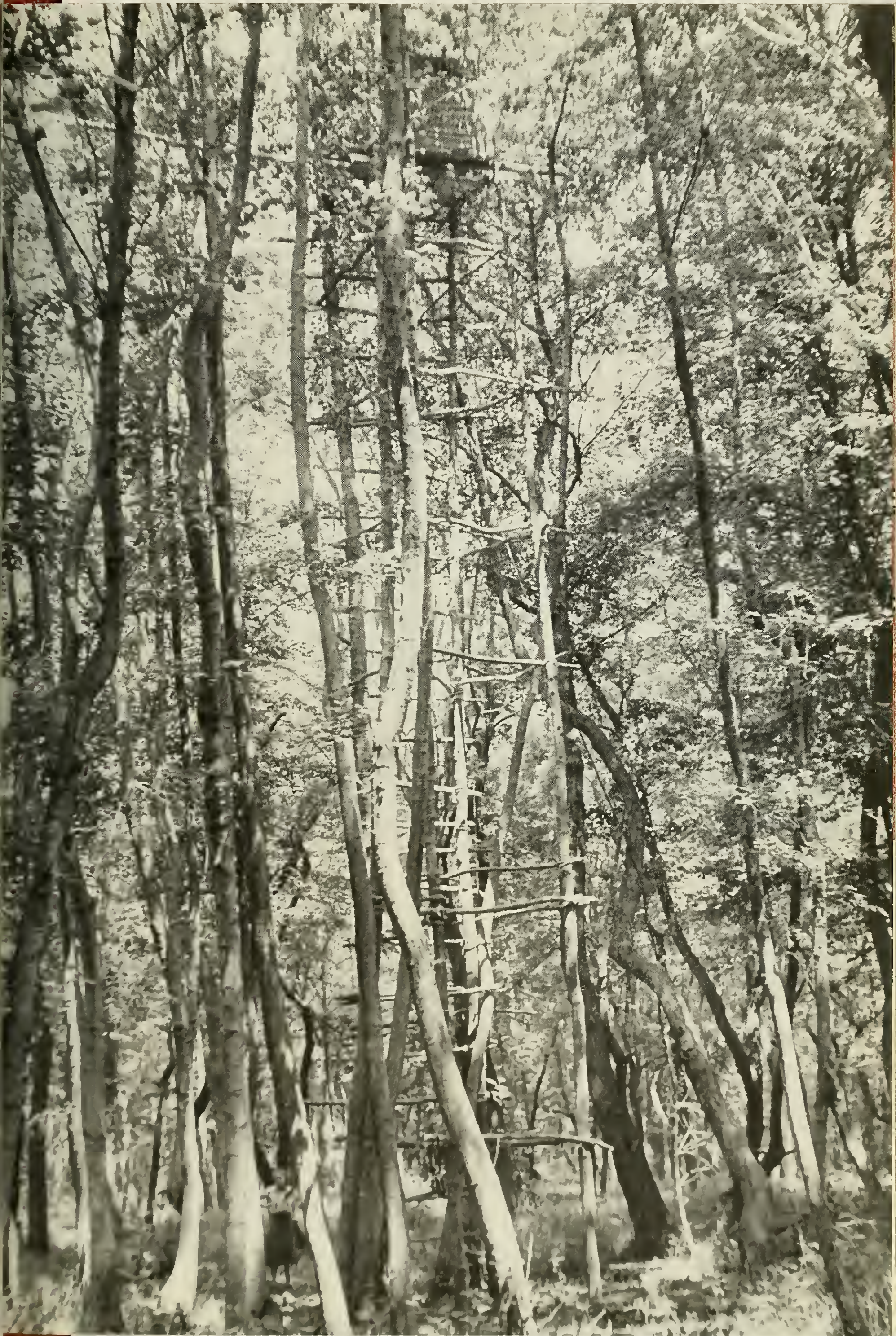


LARGE FROG, huge mouthful for small nestling, is brought to young by a rare lesser spotted eagle in Black Sea swamp forest, *above*. The bird's name is derived from white sp visible on its dark plumage only when it is still immatu



PAIR OF EAGLES, *above*, cower on nest in torrential rain. These are the first pictures ever obtained of this species.

PHOTO BLIND, *right*, was built at level of nest, 45 feet ab e the ground—to which young bird fell and still surviv l.

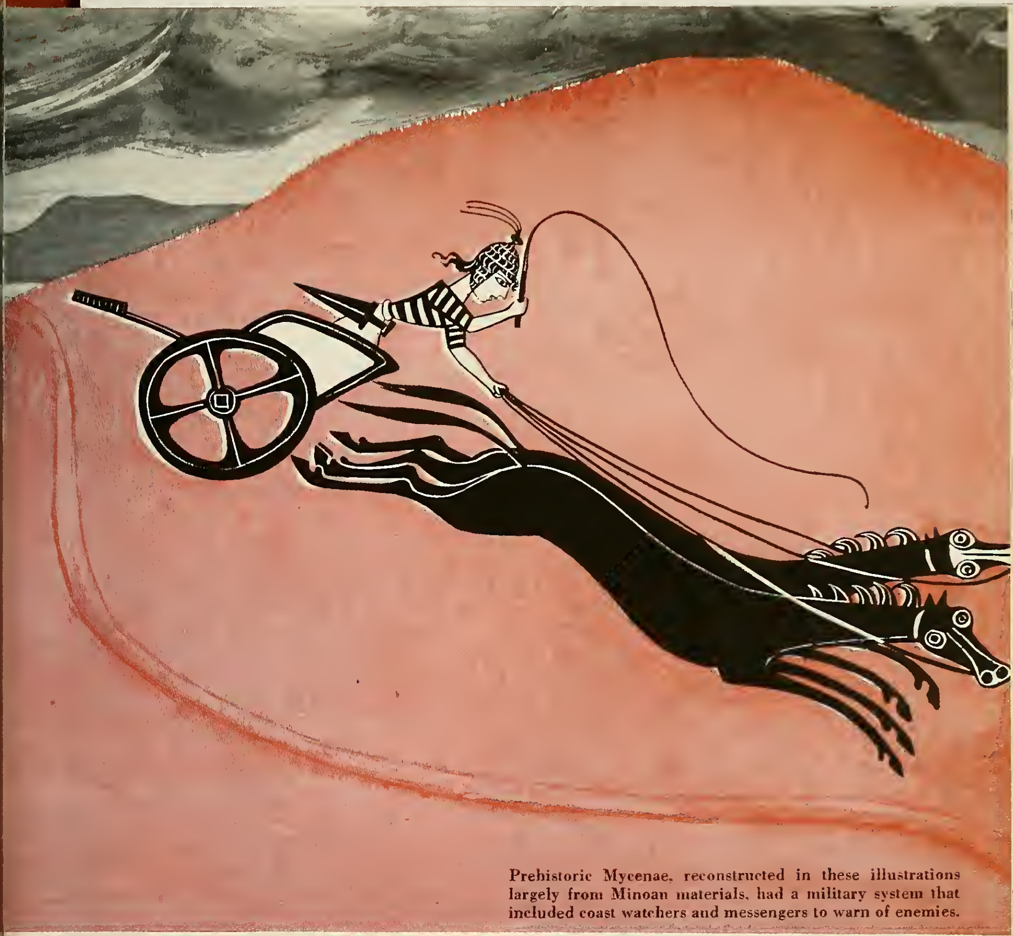


Part II

The Decipherment of Linear B

Ancient inventories throw light on Mycenaean everyday life

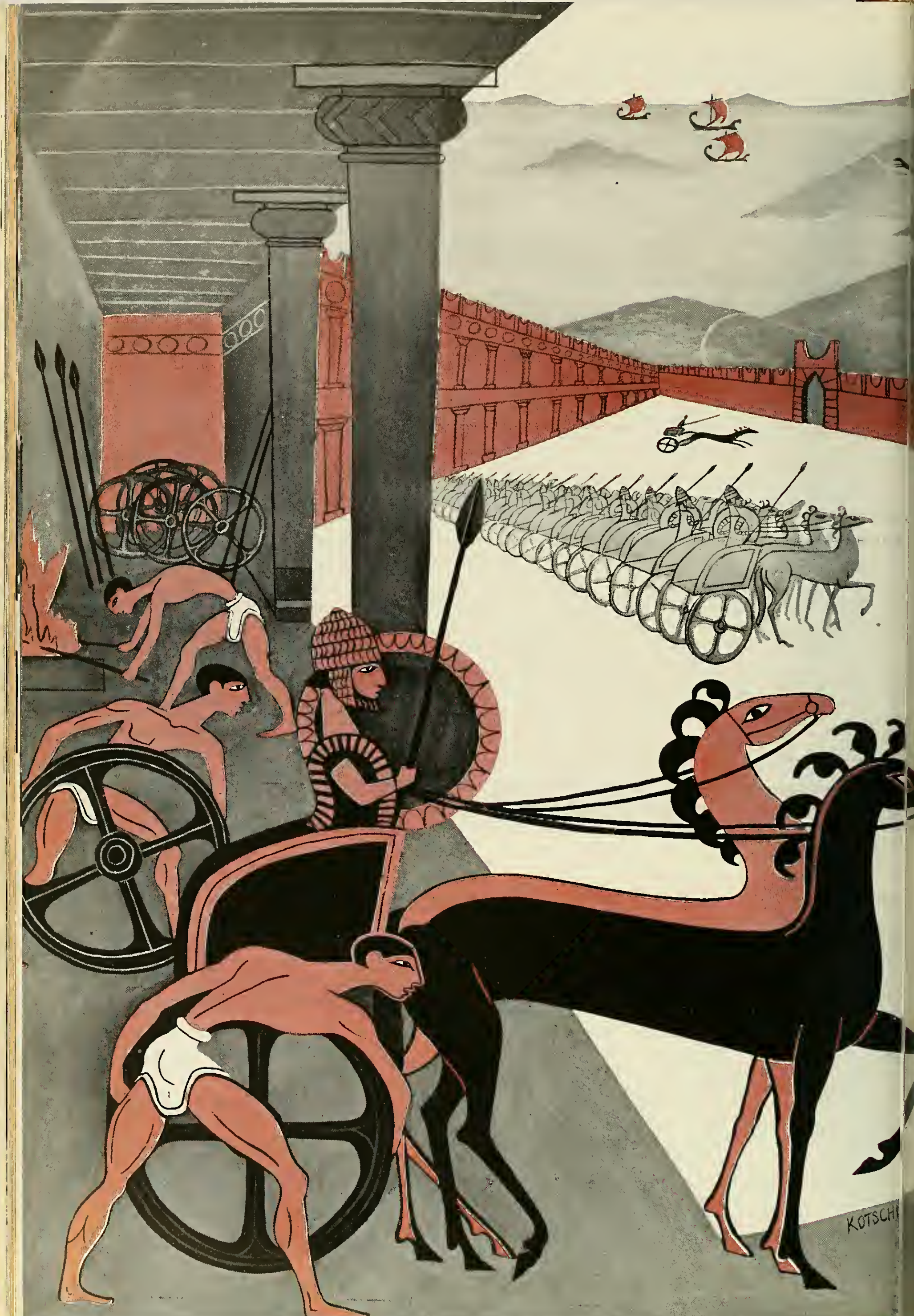
By John Chadwick Illustrations by Enid Kotschnig



Prehistoric Mycenae, reconstructed in these illustrations largely from Minoan materials, had a military system that included coast watchers and messengers to warn of enemies.

THE GLIMPSE WE HAVE BEEN GIVEN of the account books of a long-forgotten people (Natural History, March, 1961) at once raises hopes that through this means we can now gain an insight into life in the Mycenaean age. The reader will recall that three major deposits of these account books have thus far been uncovered: the first at the Palace of Knossos on Crete; the second at Pylos; and the third amid the ruins of Mycenae. Just as the Domesday Book is a vivid social document of life in eleventh-century England, so too the Linear B tablets that the late Michael Ventris first deciphered cast fitful beams of light on the domestic institutions of prehistoric Greece. There is, of course, a vast difference between these two sources. The Domesday Book is not an isolated document; it can be explained and interpreted by contemporary historical records. In Greece, an impenetrable curtain separates the fragmentary tablets from the more complete records of the historical period; during the Dark Age that followed upon the eclipse of Mycenaean civilization, the recollection of the former ways of life dimmed to vanishing point or survived, if at all, transmuted and confused in folk memory.

One fact stands out at once as of major consequence: the Mycenaeans were Greeks. Schliemann, when he excavated the first grave circle at Mycenae, had no doubt that he had unearthed a Greek dynasty. But more academic judges were not so certain, and theories of foreign domination were invoked to account for the precocious brilliance of the Mycenaeans at such a remove from the historical Greeks. Even now, two such theories have been put forward: either that the tablets were written by Greek scribes in Greek at the behest of foreign rulers; or that they were written by foreign scribes in Greek for Greek rulers. The best refutation of these theories is the existence in the tablets of large numbers of transparently Greek personal names—and these are not stratified but belong equally to all classes of society. For instance, a person of the highest standing at Pylos is named *E-ke-ra*$_2$*-wo*, which appears to be a well-known type of Greek name *Ekhelawon;* at the other end of the social


KOTSCH

This second part of MR. CHADWICK'S study of Mycenae is illustrated, as was the first part, with paintings by ENID KOTSCHNIG, based on her travels and wide art research in the region.

ale, a smith has the name *Mnasiweros* (Mindful-of-his-work) and a goat- erd has the common name *Philaios*.

The presence of Greeks at Knossos— pital of the Cretan "empire"—is still mething of an embarrassment. Pro- ssor Wace and a few other archeolo- ists had demonstrated the close links etween Knossos and the mainland in e period preceding the fall of the alace there, and even proposed to xplain them as due to mainland influ- nce on Crete, and not vice versa. The uth is that the limitations of arche- logical research preclude deductions bout the languages spoken by the peo- le studied. The physical remains may llow an anthropological classifica- on, but people of a given physical pe do not all speak the same lan- uage. The study of "cultures"—peo- les using artifacts of similar type— the archeologists' main weapon. It this study of cultures, for instance, at enables us to feel sure that, about 900 B.C., a wave of invaders entered nd settled in what is now Greece. But e inference that these invaders were e ancestors of the Greeks is based pon the knowledge that Greek was ubsequently spoken in that area, and ould not be made without recourse non-archeological premises.

THUS to expect from the archeologists a clear statement of the date hen mainland influence first appears t Knossos is to hold a vain hope. hen a half-civilized people conquers civilized one, the conquerors try to bsorb and adapt as much as they can f the superior civilization. So, especi- lly if the actual conquest is not ac- ompanied by great destruction, the vent may easily escape the archeolo- ist's spade. There is, however, one iece of evidence that proves that the reek domination of Crete was a com- aratively recent event. The use of inear A [*see* Part 1], apparently own to the early fifteenth century, is n indication that Greek had not at at time replaced Minoan as the lan- uage of accounts (unless Linear A, too, is Greek—which none but the most determined of enthusiasts will admit).

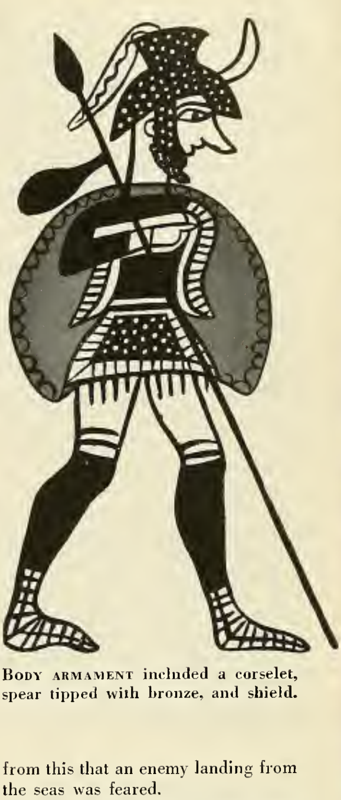
WO-HORSE CHARIOTS, characteristic of e period, were used in war and chase.

We know not only that the Mycenaeans were Greeks, but also what sort of Greek they spoke. They were not Dorians, nor apparently Aeolians; it is tempting to call them Achaeans, the name Homer most often uses for the Greeks as a whole. The name *Hellenes* does not appear until after Homer, and *Greek* is only taken from the Roman name for the peoples of Greece. What name the Mycenaeans used—if indeed they had one at all—is still a mystery. But at least we can say that linguistically their nearest relatives in the classical period were the Arcadians and Cypriots and, next to them, the Ionians.

WHAT caused the collapse of the Mycenaean civilization is a problem that has intrigued specialists for three-quarters of a century. The decipherment leaves us no nearer a solution. There is reason to believe that the last event in this collapse was an invasion of Dorian Greeks from the wild country of the northwest; but there is no proof that this invasion was the principal cause. Still, assuming that Pylos was expecting the attack, which followed soon after the tablets discovered there were written, we can even read into them references to the forthcoming event.

A number of the Pylos tablets deal with military and naval matters. One small tablet states that a contingent of thirty rowers, drawn from the coastal villages, is to go to Pleuron. Two other tablets list rowers, one showing a total of well over 400, some figures being lost; the other mentions ". . . rowers who are absent." We are tempted to speculate: were they absent on duty or absent without leave? Did the navy experience desertion in the face of impending danger? So long as less dramatic explanations are possible, it will be well not to build too ambitious a structure of assumptions on these half-understood phrases.

More significant are a group of tablets dealing with what they call *o-ka*. Despite intensive study, we are still not agreed on the details—in particular on what an *o-ka* was: probably it was a kind of military unit, perhaps a command. The introductory phrase reads: "Thus the watchers are guarding the coastal areas." It seems clear that the purpose was to establish an observation net, and we may infer from this that an enemy landing from the seas was feared.



BODY ARMAMENT included a corselet, spear tipped with bronze, and shield.

Ten "commands" are listed, each belonging to a named man; their location is sometimes given, but not always. Then follows a list of other names, presumably subordinate officers; then the forces at their disposal, often quite small and never larger than 110 men. All the detachments are multiples of ten, so that we may have here a clue to the organization of the army. Each section ends with the entry: ". . . and with them (is) the Follower So-and-so." The Followers (*e-qe-ta* = *heq*^{u}*etai*) are important men—presumably followers of the king and perhaps members of his household, like the counts of German feudal days.

Why does each unit have a royal officer, not apparently in charge, but attached? My guess is that he is the communications section. How would the watching units, spread out round a long coast line, make rapid contact with headquarters? Fire signals might be possible for an alarm; but a dispatch rider would be essential, and the Followers, as we know from other tablets, possessed chariots—the fastest means of transport in use at that time. I think that the job of the Follower was to keep the unit in touch with headquarters by means of his chariot.

If this is right we begin to see a picture of the King of Pylos organizing an early warning system; he has a long coast line to defend, and he will not be able to oppose a landing at every point. But, provided he has speedy news of the attack, he may be able to muster his army to meet the invaders. And fight he must, for the palace at Pylos—unlike its counterpart at Mycenae—has no massive walls behind which to shelter. In any event, the preparations proved vain: arrowheads and human bones found outside the palace show that it was defended; but it was burned to the ground, never to be rebuilt.

Although the destruction of the palace at Pylos was violent, we owe to that fire the survival of the clay tablets; for it can hardly be an accident that all three sites that have so far yielded tablets have been destroyed by a violent fire. Yet, of the circumstances of the attack and the fate of the inhabitants we remain ignorant.

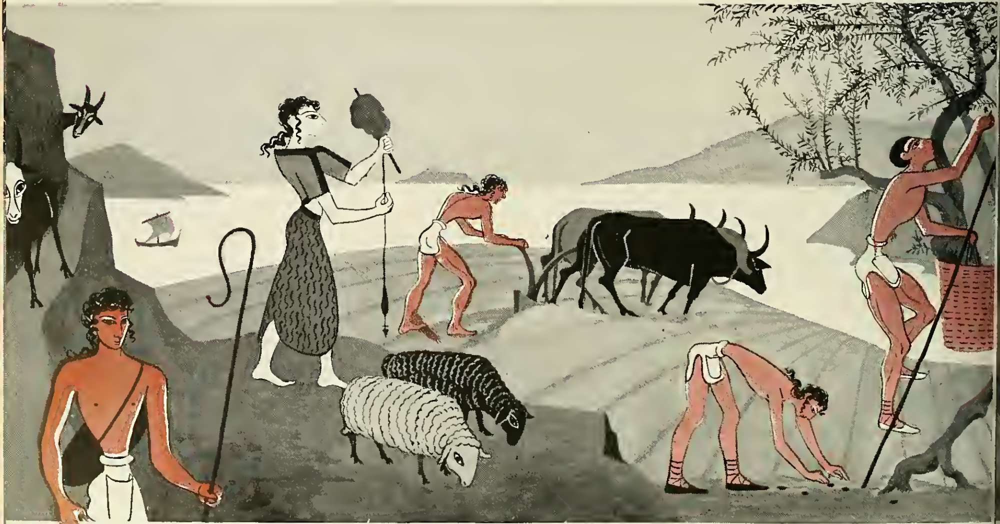
Some Cretan place names played an important part in the work of decipherment: about a dozen are now recognizable as known classical sites. Homer speaks of ninety or a hundred cities on the island, but the classical number known is much less. The sites, however, which we believe we can identify with names on the Knossos tablets, cover virtually the whole of Crete, and this seems to imply that Knossos exercised dominion over the whole island. On the other hand, no place names outside Crete can be found, so it would not appear that the Knossos of the fifteenth century B.C. was the center of a maritime empire as suggested by Thucydides; that legend must belong to another era.

Military and naval organization at Knossos cannot be traced, but we do have a certain amount of information about weapons, which enables us to reconstruct some facts about the army. The characteristic weapon of the period was the lightly built, two-horse chariot, carrying two men. Such vehicles were used for peaceful as well as military purposes, if we may judge from scenes in art.

The wheels are inventoried separately, no doubt because they were removed when the vehicle was not in use. Surprising as it may seem to us, Homer knew that the first thing to do on getting your chariot out was to put the wheels on: "Swiftly Hebe put on the chariot the curved wheels, of bronze with eight spokes, about iron axle." Some of these details not agree with Mycenaean eviden though we must make allowances the fact that Homer is describing divine chariot. For instance, Mycen an wheels always have four spok and although one pair at Knossos described as "of bronze" it is hig doubtful that the whole wheel made of this material.

The usual wheel material listed the Knossos tablets is willow or el three pairs made of cypress wood recorded. Tires of some sort seem have been fitted, and some were bou with bronze. Indeed, one pair bound with silver. One Knossos tal mentions as many as 462 pairs.

One series of Knossos tablets undoubtedly the muster roll of armored brigade: each tablet reco a man's name, a chariot complete w wheels, a cuirass, and a pair of hors In a few cases there is only a sin horse, which may mean that the ch iot was not operational. The total not easily computed, since many the tablets are fragments; but I co eighty-two chariot ideograms, wh gives the minimum figure. We sl probably not be far wrong if reckon on a chariot force number well over a hundred. Each chariot managed by a driver (a charioteer



Country life reflected the simple agricultural econo Goats and sheep were kept, and women spun wool. O specifically mentioned by one Knossos tablet, but this muster roll contains only one name for each chariot. presumably that of the warrior); the warrior passenger was thus free to fight.

In Homer, chariots seem to be little more than taxicabs, taking the warriors into and out of battle; but this may be, in part at least, owing to the fact that Homer, writing in an age when the chariot had long been obsolete, had forgotten their true use. A formation of a hundred massed chariots charging at a gallop would have been a formidable spectacle; and Homer does appear to recollect such tactics; Nestor advises such a formation, and implies that it is no longer usual. But massed chariots could only have been deployed in open country. In many parts of Greece, the opportunities for such tactics must have been limited, and the chariot force would therefore have been used more as motorized infantry than as tanks.

Unfortunately, the Pylos chariot inventories have not yet been found. Possibly, as at Knossos, they were kept in a separate office outside the main archive room: but they must have existed, for we have plenty of records of wheels. As usual, the scribes were more explicit at Pylos than at Knossos: the wheels are carefully distinguished as serviceable or unserviceable, and some have other epithets, such as "old." A rather surprising feature is the enumeration of wheels as "of the Followers." This implies that the Followers of the royal house were in effect the king's chariotry, or at least an important part of it.

The total number of serviceable wheels recorded in the Pylos tablets is in the region of eighty-four pairs; but how many spares were needed for each chariot we do not know. If the roads round Pylos were anything like what they are today, any one pair would not have lasted long.

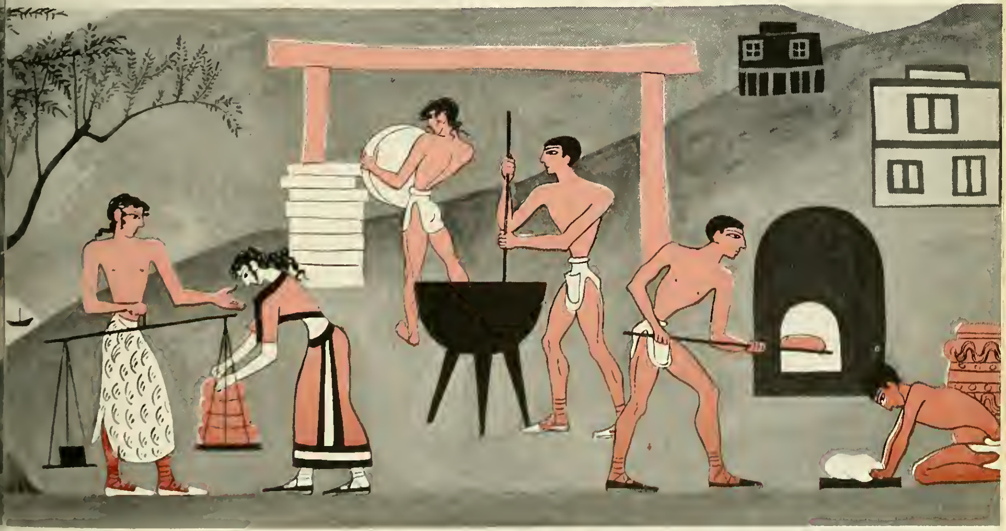
The body armor worn by the Homeric heroes has been endlessly debated. Efforts have been made to reconcile the descriptions with the archeological evidence, not always with success, and we must allow for anachronisms here as in other parts of the poems. If we study the tablets, the picture becomes a little clearer, for we are lucky enough to have inventories of armor from both Knossos and Pylos that agree in broad outline.

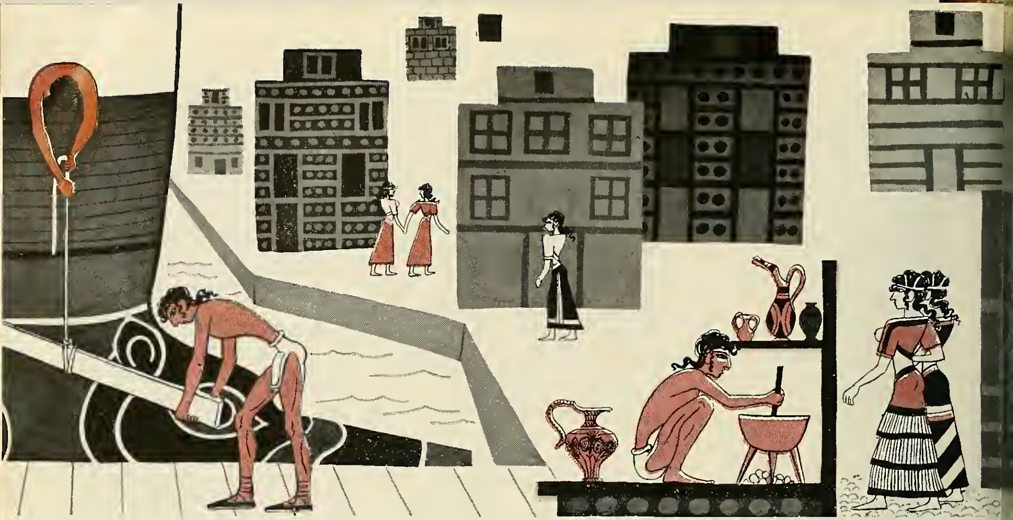
The helmet is of a simple, conical shape. We are not told of what material it is made, but leather is a fair guess, for it has attached to it four "plates" or "scales." The word so translated is not identified with an attested Greek word, but the general sense seems clear from its use. How these plates were arranged, or how large they were is not specified, but it may be significant that their number is usually the same at both places, although one Knossos tablet mentions only two plates. Cheekpieces must also have been attached to the helmet.

The body was protected by a corselet or cuirass. Again, the material is not specified, but one tablet hints at linen. Attached to this cuirass were some thirty or more plates (again the same word), twenty large and ten small, or in some cases twenty-two large and twelve small. These figures on cuirass plates are from Pylos: relative parts of Knossos tablets are lost.

The weapons carried by the charioteers were their spears; wooden shafts, tipped with bronze points. At Pylos, bronze is requisitioned to make "points for spears and arrows." Swords are shown on tablets at Knossos—called by their Homeric name, *phasgana*—of the broad, two-edged type well known archeologically. There is a slight difficulty here, since the type of sword shown by the tablets is not otherwise known until a slightly later period. Pylos adds the classical word for sword, *xiphos*, but this would appear to be rather a thin rapier, to judge by the way it is drawn. Arrows are several times mentioned, and a labeled box

were used primarily as draft animals. Chores included olive gathering, weighing the grain, and making cheese and bread.





City life showed specialization of labor. Shipbuildi
manufacture of perfumes and pottery, and masonry was t

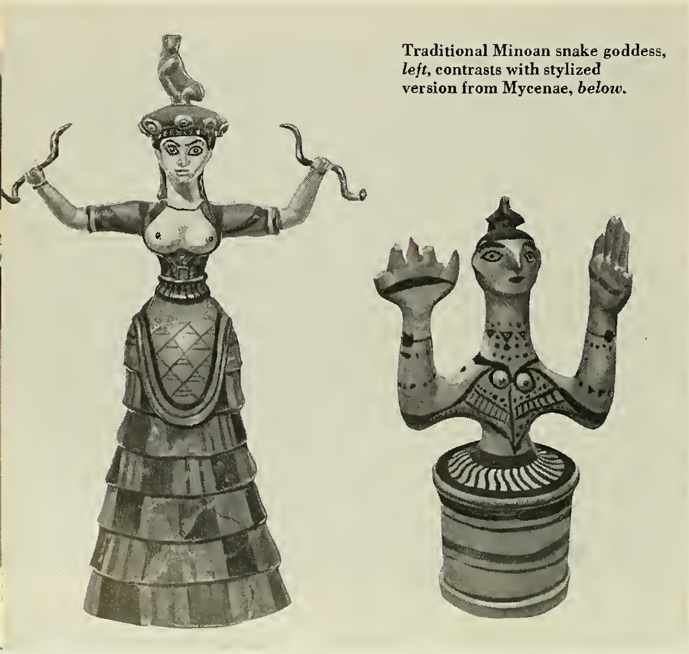
of arrowheads was found at Knossos; one tablet there gives two totals of 6,010 and 2,630 arrows.

There are two curious gaps in our picture of Mycenaean armor. First, there are no greaves, although "well-greaved" is a favorite Homeric epithet of the Achaeans (and, once, "bronze-greaved"), and the archeologists have recovered them at least from contemporary Cyprus. Secondly, and much more surprisingly, there are no shields. This is an extraordinary omission from the records; we must hope it will eventually be made good, for shields they must have had, and the figure-of-eight shield of early Mycenaean times remained a favorite decorative motif in art.

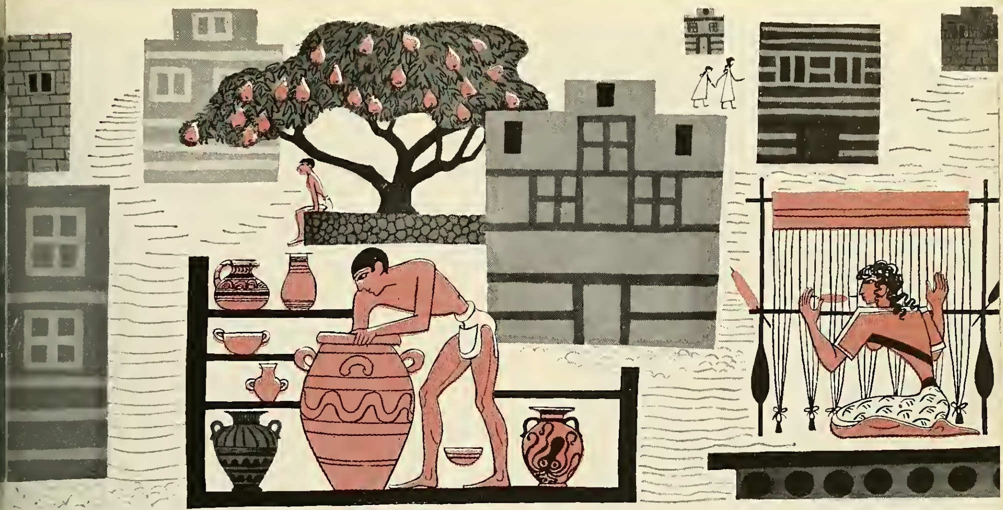
We know virtually nothing about
Mycenaean military organization b
yond what has been said above. B
a few details of the political and soci
structure can be picked out amid t
general obscurity. Both Knossos a
Pylos were monarchies, for bo
places mention the king *(wanax)* wit
out any further qualification, whi
must mean that there was only on
although there is the added complic
tion that the same title seems to
applied to gods as well. The conclusi
that the kingdoms were monarchi
governed by a highly organized b
reaucracy, may also be drawn fr
the complex palaces that have be
found. This fact justifies us in exten
ing the deductions from the Knoss
and Pylos tablets to Mycenae as w
where the tablets do not provide a
direct evidence for the social structu

There is also an important offic
called the *Lawagetas*, or "Leader
the Host," who seems to rank next
the king. I wondered at first if t
might be a title for the heir appare
but Palmer, pointing to the etymolo
cal meaning, has suggested that he
more likely a Commander-in-Chief.
and the king are the only two peo
who have a household includi
tradesmen; just as we meet "the kin
fuller," so we meet "the shepherd
the *Lawagetas*." These two also sh
the honor of a *temenos*, the royal la
holding in Homer, which in la
Greek has religious associations.

The whole question of land ten
is still hotly disputed. Despite a wea
of documents at Pylos, the exact me



Traditional Minoan snake goddess, *left*, contrasts with stylized version from Mycenae, *below*.



ork of men. Weaving was a woman's occupation, although appears that tailoring was done by men as well as women.

g of the constantly repeated formus remains obscure; and almost the hole of the Pylos tablets dealing with is subject relate to one village, which ay not be typical. Since there the ajority of landholders have religious tles. it may be an unusual settlement.

The scheme of land tenure here can e worked out in some detail, but what es behind the bald facts is still a matr of conjecture. Land is divided into o types: *ke-ke-me-na*, which is held rom the community (*demos*), and ay therefore mean something like common"; and *ki-ti-me-na* = *ktimea*, which is in the hands of individuals apparently *telestai*), and etymologially means something like "reclaimed rom the wild," "established"—thus erhaps "private." The large landolders yield a portion of their *ktimenā* nd to "tenants"; but it must not be pposed that this word implies an acal lease and the payment of rent; we re still far from understanding what e economists call the circulation.

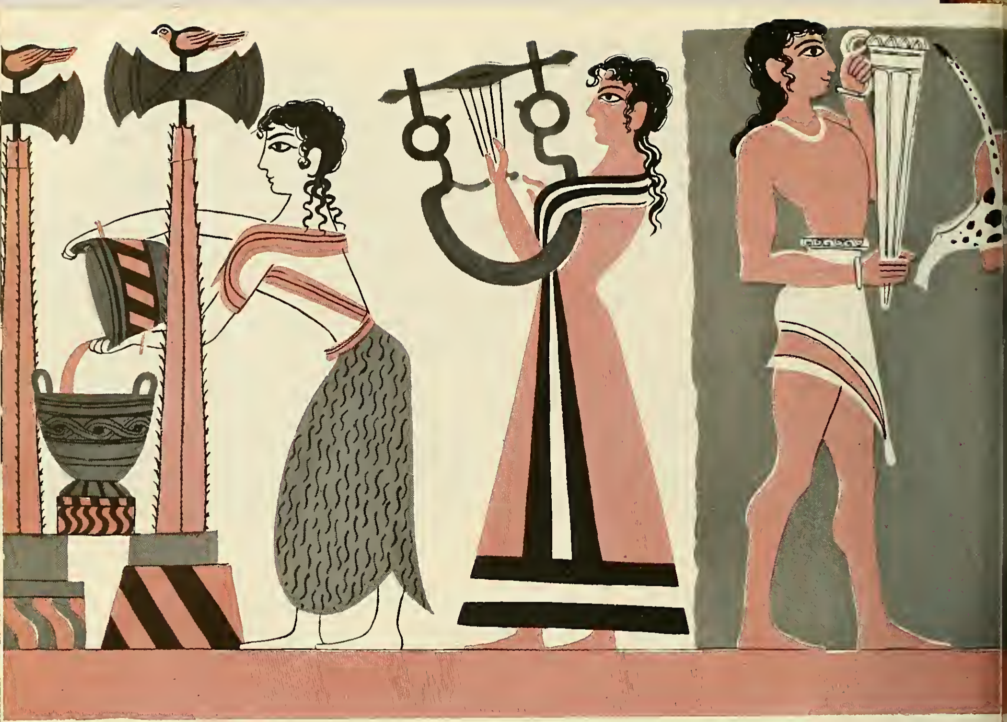
At the lower end of the social scale e find the slaves. How far society as founded upon slave labor we canot tell. nor do we know if slaves possed any rights. An elaborate index t Pylos records over 600 women, toether with about the same number of hildren. That they are slaves is clear rom a variety of indications: some re specifically called "captives" and any are assigned to menial work grinding corn, carrying water, spining, and so on). They are not all oncentrated in the Palace, but are allocated to other places as well, possibly country houses of the royal family, since their rations are issued by the Palace. But even more interesting than their occupations are the descriptions that betray their origin. Three such epithets clearly relate to places on the eastern side of the Aegean: Lemnos, Knidos, and Miletus. The last of these brings us into contact with the Hittite records, for we know that the king of Ahhijawa, who seems to have been a Greek, controlled a place on the Asiatic coast with a name like Miletus. So these places may be Mycenaean colonies or outlying possessions that traded in slaves. Alternatively, we may conjecture that they are the product of piratical raids on a hostile coast, and that the ships of Pylos ranged far and wide across the Aegean.

Many of the tablets describe men or women by their occupations, and this enables us to form some idea of the complexity of urban life and the specialization of labor. Spinning of yarn and weaving of cloth are women's occupations: carders. spinners, and weavers are specifically named, as well as flax and wool workers. Sewing, however, appears to be done by men as well as women; we find tailors as well as seamstresses. The cleaning of garments is the task of a fuller; the king has his private fuller.

A variety of manufactures can be deduced from these occupational terms; carpenters and masons are constructional workers whom we should expect to find; ships are built by a special class of shipwrights, and calkers possibly have their separate trade. Weapons and other metal goods are made by bronzesmiths. Bronze is, of course, still the chief metal in use, articles of iron being very rare and never mentioned in the tablets. Lead is mentioned once at Knossos.

The precious metals include gold, worked by goldsmiths, and used for some vessels and for inlay on furniture. If we look at the actual finds, we shall observe that the goldsmiths also made jewelry; the craftsmanship and artistry of known Mycenaean gold work is of the highest order. Silver, which is not uncommon among the archeological finds, occurs only once on the tablets—a fact that has made us suspect it is sometimes mentioned under another name. The existence of bow-makers is a typical example of the degree of specialization prevailing. The luxury trade is evidenced again by the existence of unguent-boilers or, as we should call them now, perfumers.

A number of tablets enable us to see a little of the perfumers' work: they were issued with olive oil as the base, and this was boiled with aromatic substances to make perfumed oil and unguents. We can list three perfumes: rose, Cyperus, and sage. The use of these perfumes is somewhat unexpected: they were sent to the shrines as religious offerings. Whether the Mycenaean ladies also used them we are not told in the tablets, but the numerous perfume flasks found in



Aspects of sacrifice as found on such Minoan objects a
sarcophagus from Hagia Triada are combined here. In he

women's graves tell their own story. One mention guarantees the existence at Pylos of a physician; unfortunately, we know nothing of his methods or status, except that he appears to have received a grant of land.

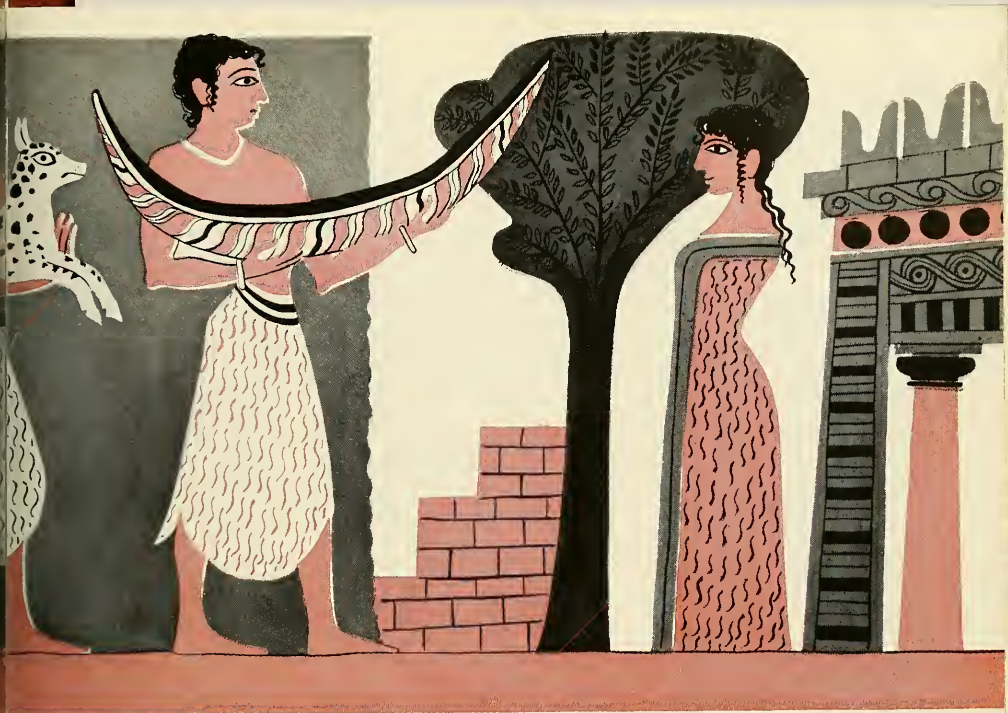
Agricultural organization is more simple: shepherds, goatherds, and cowherds show what were the principal domestic animals. In Crete, a vast archive of records bears witness to the immense scale of sheep farming, still an important industry there today. Oxen are much less numerous, and seem to have been used mainly as draft animals; they are sometimes called "workers." It is fascinating to see the names given to a few yoke of oxen: Dapple and Darkie, Whitefoot and Winey, Blondie and Bawler are rough equivalents. A reference to the class of men called "yokers" may mean ox-drivers who attended a yoke of oxen.

Pigs were kept: we have a list of twenty-five, which were being fattened at villages in the kingdom of Pylos. A few tablets mention deer; these are presumably the carcasses of wild animals. Dogs were used for hunting, if we may trust the word for huntsmen *(kunagetai)*, which is, etymologically, "dog-leaders." Horses are rarely mentioned except in connection with chariots; asses are listed only a single time.

The staple item of food was doubtless grain, of which two kinds, probably wheat and barley, are recorded by means of ideograms. It was measured out and ground by women, but the bakers were men. This bread and porridge diet could be enlivened by spices; coriander is the most frequent, but a list from Mycenae includes also celery, cumin, Cyperus, fennel, mint, pennyroyal, safflower (both flowers and seeds), and sesame. Cheese is among the shrine offerings, and was no doubt eaten on a large scale. Figs are another item of diet; the Pylos slave women's rations surprisingly contain the same quantity of figs as of grain. Olive oil and olives were consumed. Another ideogram is plausibly identified as wine, the existence of which can be deduced from the name of one of the oxen mentioned earlier.

An obvious question, to which ther
is no obvious answer, is: where di
the wealth of these kingdoms com
from? Articles like ivory and cumi
must have been imported from th
East; the copper and tin for bronz
were not to be found in Greece. Th
only goods available for export seen
to have been agricultural produce an
possibly manufactured goods such a
pottery, including re-exports in th
form of craftsmen's work. The recon
struction of the economy is a compli
cated task, in which there are to
many unknown factors for it to b
more than conjectural. We may pos
sibly have to take into account hidde
sources of wealth in the form of var
ous kinds of loot, including captive

But we do know something of th
internal economy of the kingdom
Not only was there no coinage—coir
were an invention of the seventh ce
tury B.C.—there was apparently n
commodity in which values could l
expressed. The other ancient civiliz
tions of the Near East valued goods i
terms of gold and silver; nothing
the kind has so far appeared on Myc



nvocation to dead, priestess pours libation as music is layed and priests offer cup, calf, and boat to the departed.

aean texts, despite numerous atempts to read such a meaning into ertain texts. It was, therefore, necesary for the circulation of goods to be neasured in kind: when villages were ssessed for what we may call tribute, hey were required to produce so much f a number of specified commodities.)n the other hand, the central organzation distributes goods to these same illages, or to groups of workers and ndividuals. The means by which acounts were balanced, if such a metahor may be excused, is not known; ut we can be sure that there were bligations on both sides. The difficult hing for us to grasp is the absence of nything that can be called payment.

Two sets of documents may be selected as typical of these operaions. First, the long series of tablets rom Knossos recording sheep: the otals for some districts run to several housand, and one tablet mentions as nany as 19,000. The individual enries, each on a separate tablet, follow general plan: a man's name, apparntly the owner or keeper of the flock, heads the tablet. Then we have a note of the district, and another man, who appears to be the responsible official of the Palace or tax-officer; and finally the number of sheep. Sometimes this is simply an entry such as "100 rams"; but more often it is broken up into categories thus: "28 rams, 22 ewes; deficit 50 rams." This means that the total assessed was 100; the first two figures record the payment made, the last the balance due. It is significant that in these cases the total, which is not actually expressed, is almost always a round number, most often 100, but numbers like 50, 150, 200, and 300 are also found. Sundwall, who first noticed this feature, thought that the animals were oxen, not sheep, and that they were hecatombs (hundreds) of sacrificial animals. The numbers involved would have made the Cretans astonishingly pious; we must be content with a less picturesque explanation. The sheep must be tribute, because a census is excluded by the round numbers and the calculated deficit. There is another queer thing about these tablets: rams heavily outnumber ewes, not merely in the deficit, which is ordinarily reckoned in rams, but in the figures of sheep received. This must mean that the keepers picked out the members of the flock least useful for its regeneration. Thus we arrive at the conclusion that these large figures represent only a fraction of the total, and a sheep population running into several hundred thousand must be supposed for the whole of Crete—by no means an improbable figure. We can only speculate on what became of the sheep thus contributed; the altar and the kitchen can hardly have accounted for them all, unless meat was eaten on a much greater scale than in classical Greece. In some cases not only sheep but wool too is recorded.

How great was the part played by religion in everyday life we may conjecture both from the numbers of votive objects that have been recovered by the excavators from some shrines, and from the numerous tablets that deal with offerings. But it is no simple matter to identify the deities. The only ones of which we feel sure are those whose names we recognize as equivalent to classical ones. Associated with them are a host of strange names, which may or may not be divine; the listing of offerings to human representatives of the deity, such as the Knossian wind priestess, is a warning against jumping to conclusions.

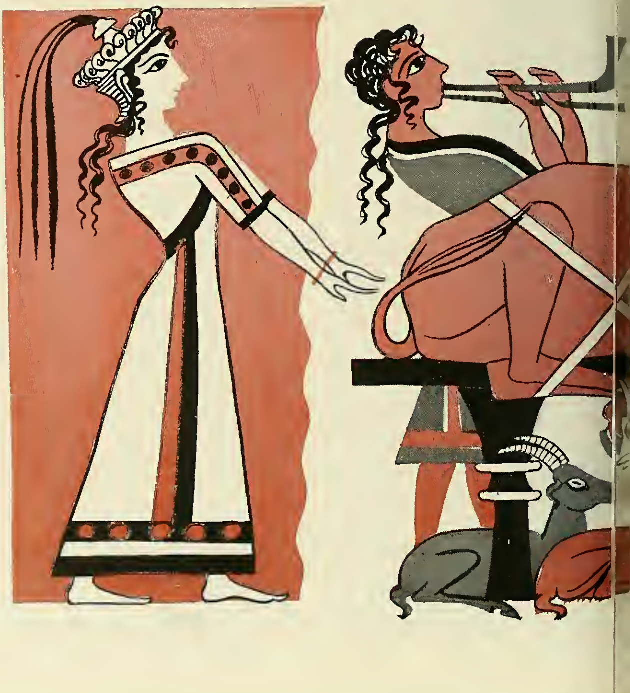
The recognizable deities are the familiar names of classical Greece: Zeus and Hera (already coupled), Poseidon, Hermes, Athena, Artemis. *Paiawon* is an early form of *Paian*, later identified with Apollo. Homer tells us that Odysseus stopped "at Amnisos, where is the cave of Eileithyia." With this clue, the archeologists were able to locate a cave on the coast of Crete, not far from Knossos, which had been in use as a shrine from Minoan times onward. What then was more natural than to find a tablet at Knossos recording the dispatch of a jar of honey to Eleuthia at Amnisos? Eleuthia is a known form of the name Eileithyia, who was the goddess of childbirth.

At this point we begin to pass from the known to the unknown: the Knossos dedications "to all the gods" are not really intelligible, for such a pantheistic cult was not known before Hellenistic times. The worship of the winds is another unfamiliar, although not unknown, cult. But the most curious divine title is a well-known Greek word: *Potnia*, "the Mistress," or, as we would say, Our Lady. Once this title is coupled with Athena in a way that recalls Homer's use of the word as a title for any goddess. But as a rule the word stands alone or in connection with a place name: "Our Lady of the Labyrinth" is surely the most striking dedication to have been discovered out of Knossos.

The usual view in modern times is that the classical Greek religion is to some extent a coalescence of two distinct beliefs: a group of Olympian or celestial deities (a concept shared by other Indo-European peoples); and a chthonic or earthly group, living in the underworld and dominated by a goddess of fertility known to the classical Greeks as Demeter. We know from Minoan and Mycenaean monuments that a female deity played a prominent part in their religion, and I have therefore suggested identifying Potnia with this figure. No certainty is to be reached in such matters, and we must be careful not to equate Potnia with the classical Demeter. There is, however, a powerful argument in favor of a mother-goddess to be drawn from a tablet discovered at Pylos in 1955, which records an offering of oil to the "Divine Mother," a title strongly reminiscent of the later "Mother of the Gods." It can hardly be denied now that a cult of this type was known in Mycenaean Pylos.

The gods are mentioned in one capacity only, as the recipients of offerings. These are sometimes animals, and we can presume a ritual of sacrifice. Poseidon, on one tablet, receives one bull, four rams, quantities of wheat, wine, and honey, fifteen cheeses, some unguent, and two sheepskins. This sounds like the provision for a ceremonial banquet, and an interesting illustration of such a ceremony is to be found on a painted sarcophagus from the Cretan site of Hagia Triada. But the commonest offerings are of olive oil. A series of tablets from Knossos are lists of quantities sent to miscellaneous divinities; but a parallel group was lacking from Pylos until 1955, when Blegen uncovered the oil magazines at the back of the Palace. In these were found large storage jars and a group of tablets recording the distribution of the oil, most of which was perfumed. The recipients are usually Potnia, Pose don, and the king (who, in this co text, may be a god—perhaps on another name for Poseidon). In tw cases, the oil is described as "for spreading of couches," a name for ritual meal offered to the images the gods well known both in lat Greek and in Roman rites. In anoth case we are told that the perfume w "for the anointing of robes."

One odd omission from our li of Mycenaean occupations that of scribe; here the omission almost certain to be due to our i norance of the correct word, and t title may underlie one of the ma uninterpreted words of this group. W might have expected the classic Greek word *grapheus* to be in use, f *grapho* "write" meant original "scratch," a suitable designation the process of writing on clay. B the Cypriots of classical times p ferred another word, *alinō*, meani originally "paint"; and if, as in many things, the conservative Cyp ots had retained an old word for wri we might expect this root in Myc naean. We do once meet some m called *aloiphoi*, but they may be pai



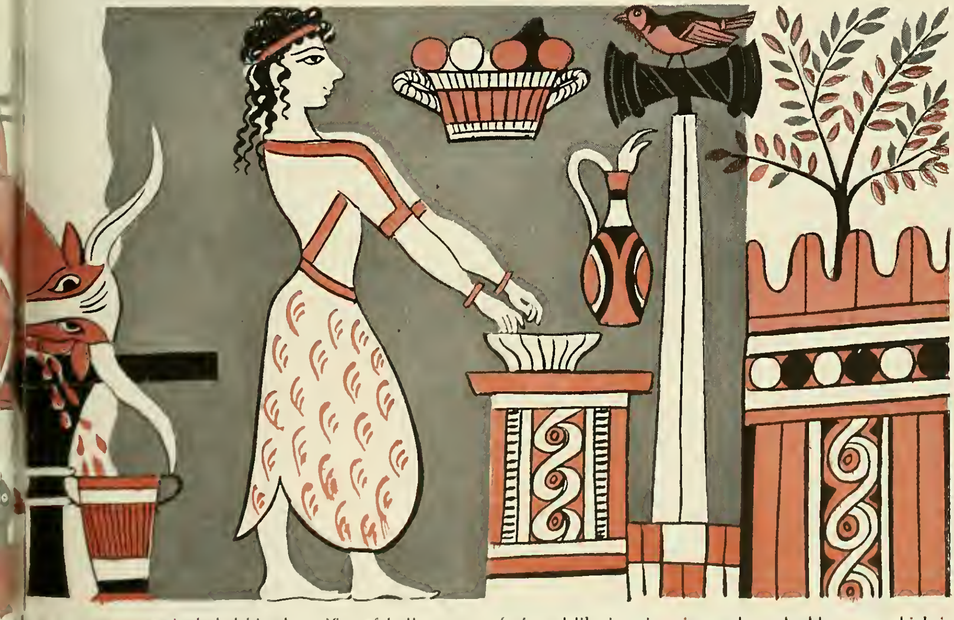
e or greasers rather than scribes. Akkadian cuneiform tablets frequently bear the name of the scribe wo wrote them; but not a single Myaean tablet has a signature of this kd. It would appear that the writing a tablet was not a matter of pride the scribe; we have no parallel to scribe of Ugarit who signs himself aster-scribe." Nor apparently was tre any need to have the responsible sibe's name as a check against wrong eries. However, modern ingenuity h to some extent triumphed over ts tiresome omission of the ancients. nett has made a thorough study of cenaean handwriting, and although full results are not yet published, s already clear that a large number ohands are represented at each site. ch scribe has his own idiosyncras; and to the practiced eye the near B script shows just as many ierences as modern handwriting. v tablets are in copperplate; many carelessly written, and there is nty of scope for variation when the sipt uses so many characters.

The tablets found in one building Mycenae produced evidence of six ferent hands; and the complete colltions of Pylos and Knossos each required thirty to forty scribes to write them. These figures would be without significance, were it not certain that all the tablets from each site are contemporary within narrow limits. How can we tell that tablets fifty years old were not in the archive room when it was burned? The answer, as so often, is indirect. If you are keeping accounts for a period of years, you must date them in a way that will enable you to know which belong to the current year and which to past years. But, again unlike many Akkadian texts, Mycenaean tablets never have a year date. Hardly any have a date at all; those that have (and they seem generally to be religious texts) are dated by the name of the month alone. Six month-names are known at Knossos, two at Pylos; there is no overlap between known sets; one Knossos month-name recurs in classical Arcadia.

By contrast there are several mentions in the tablets of "this year" *(toto wetos)*, "next year" *(hateron wetos)*, and "last year's" *(perusinwos)*. These phrases would be meaningless, unless the tablets were current only for a year. This seems to imply that at the beginning of every year the tablets were scrapped and a new series begun.

BUT, someone will say, the dates may have been not on the documents themselves, but on the filing cabinets. There is an answer to this, too. We know a good deal about the filing system from the excavators' reports. Some tablets were apparently kept in wooden or gypsum boxes; but the majority seem to have been stored in wicker baskets, and when complete the file was marked by a clay label. We have a fair number of these, distinguishable because their back is marked by the pattern of the basketry, where the soft clay was pressed into it. They are in general rather badly preserved, and it was only recently that I thought of sorting them according to the tablets they had labeled. A few were obvious; and others could be restored by comparison with the relative tablets; but in no case did the label appear to have borne more than a few words serving to classify the contents. For instance, the basket containing the corselet tablets was baldly labeled "corselets"; one of those dealing with wheels was more explicit; it read "serviceable wheels for Followers." It is clear that these labels certainly did not contain the missing date.

Another argument also confirms the



RTHER CEREMONIES included blood sacrifice of bull as a uble flute was played. Next, priestess offers basket of fruit and libations in a jug under a double ax on which is perched black bird signifying Goddess of Death's presence.

absence of old records: the absence of duplicate sets. Every year similar sets of returns must have been compiled; yet with two possible exceptions no duplicate sets have been discovered. Neither of the exceptions is a simple duplicate; one gives additional details, the other appears to be a writing-up, with minor changes, of the information on one set of tablets into a tabulated form. Thus, the records of previous years are clearly absent from our finds; and this means that all the tablets from each site can be safely presumed to have been written within twelve months or very little more. By such a roundabout means we reach the conclusion that writing was by no means rare in the royal palaces.

But how many people outside could read and write? There is a negative piece of evidence that cannot be dismissed on the ground that insufficient sites have been excavated. There is not a single stone-cut inscription known in Linear B; no gravestone bears the name of the dead, no public building the name of the builder. Were it not for the tablets and inscribed jars, we should still think of Mycenaean Greece as illiterate. And this is the more remarkable because Linear A inscriptions have been found on stone and metal objects in Crete.

LASTLY, we must deal with a thorny problem: what light do the tablets cast on the Homeric poems? At present there are two schools of thought: those who believe that the Mycenaean element in Homer is great, and those who think it is small. A compromise is here the best solution. We cannot deny that many features of the Homeric world go back to Mycenae.

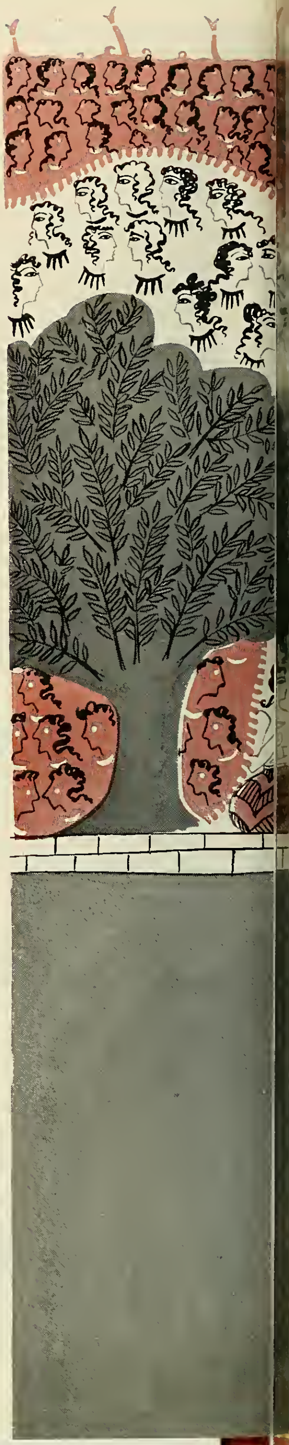
To take a famous instance, Homer describes a curious kind of helmet made of felt to which are sewn rows of plates cut from boars' tusks. This was an unexplained oddity until a tomb was opened that contained a great number of pieces of boar's tusks, and Wace demonstrated that they could be mounted so as to make just such a helmet as Homer describes. But a helmet of this type can hardly have been known in the eighth century B.C. Its description must have been handed down orally for centuries. If this is true of one detail, why not of others?

Again, consider the queer, archaic language that Homer uses: it must have sounded to the classical Athenians rather as Spenser's *Faerie Queene* sounds to us. Elements in it clearly come from a Mycenaean source: the case-ending *-phi*, for example, is unknown in any later dialect, but is common in Mycenaean. All this can be made to add up to a strong case for the preservation of a large Mycenaean element in the epics: in this view, the Trojan War is a historical event and Homer a guide to Mycenaean Greece.

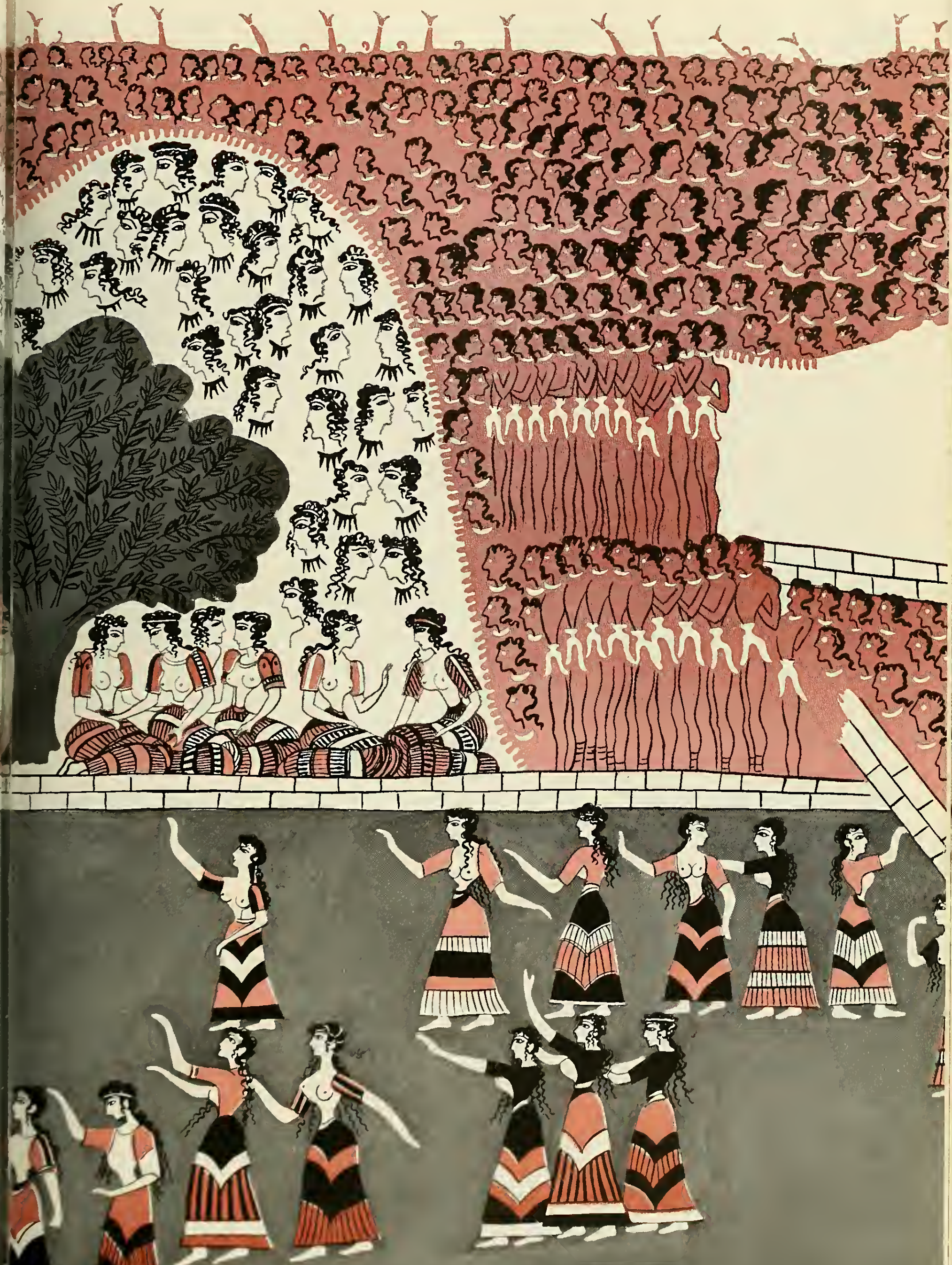
ON the other hand, when we compare the tablets with Homer in any detail, discrepancies are immediately obvious. The position of the king may well be the same in both Homer and the tablets; but what has happened to his second in command, the *Lawagetas?* Not only is his name unknown to epic verse, but there is no term that serves instead. So, too, repeatedly with other features: it is all very well to say that Homer was not interested in details of land tenure, but the common Mycenaean term for a plot of land never occurs in the poems.

Several Pylos tablets list, in a consistent order, a group of nine important villages: the coincidence that Homer, in the "Catalogue of Ships," also assigns nine towns to the Pylian kingdom was quickly noted. But the two lists do not match. Homer's includes Pylos; that of the tablets excludes it, and only one of the remaining eight names is the same in both lists. Homer's language contains Mycenaean elements, it is true, but much is of far later date, and the old and new are mixed in such confusion that the attempts of scholars to separate them have produced little agreement or progress. It would seem best neither to exaggerate nor to underestimate the Mycenaean relics in Homer.

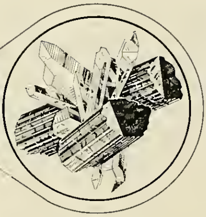
Whatever position is finally adopted in this controversy, it is fair to say that Ventris' accomplishment in the decipherment of Linear B has brought an entirely new element into the Homeric problem. It has provided the dumb monuments of prehistoric Greece with a linguistic commentary—incomplete and obscure, but a guarantee that their makers were Greeks. It has pushed back by some seven centuries the date of the earliest Greek inscriptions, and thus given the Greek language a continuous recorded history totaling thirty-three centuries, a record that is rivaled only by Chinese.



DANCERS entertain both aristocracy and commoners in open-air amphitheater.



NATURE IN
ROCK & MINERAL



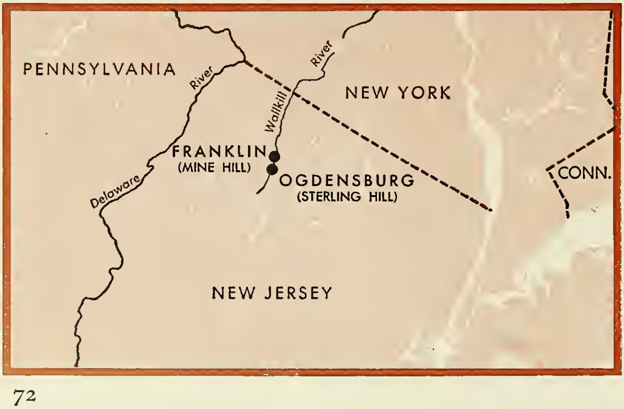
By Paul Mason Tilden

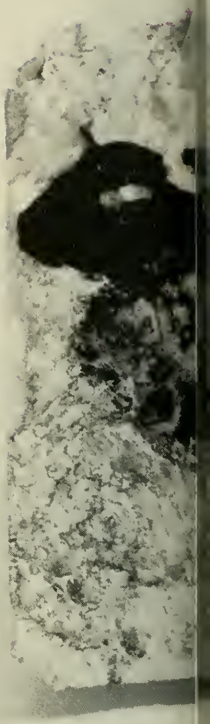
The sum of the wealth that has been won from the mines and quarries of this nation since early days would, in terms of dollars, run into countless billions. Indeed, the sum total can never be more than approximately estimated, since production records of earlier times are often conflicting, inaccurate, or even entirely nonexistent.

In assessing this vast production by national geographic province, we seldom think of our eastern coastal states as substantial contributors to the total, either during past or present times. We are more likely to think of that part of the country as the erstwhile locale of many small and short-lived adventures in iron-making, the hewed stone furnaces for which were fired by charcoal and fed with bog hematite or vein magnetite. We think, too, of this most easterly tier of states as an area peppered since Colonial days with small, sporadically operated and generally uneconomic "prospect holes," quite often explored at the public expense by way of common—and soon worthless—stock certificates.

Such a casual picture is partly, but not wholly, accurate. It is true that this eastern geographical province—for the present purpose roughly defined as the area between the Atlantic shore and the summit of the Appalachians—has never afforded such phenomenal producers as the "Homestake" of South Dakota's Black Hills, whose deep shafts have spewed forth some half-billion in gold since 1879; nor has it ever boasted bonanzas like the "Sunshine" mine of Idaho's Coeur D'Alene mining district, whose quartz veins have yielded as much as twelve million ounces of silver in a single year, making them the world's second largest producers of this metal.

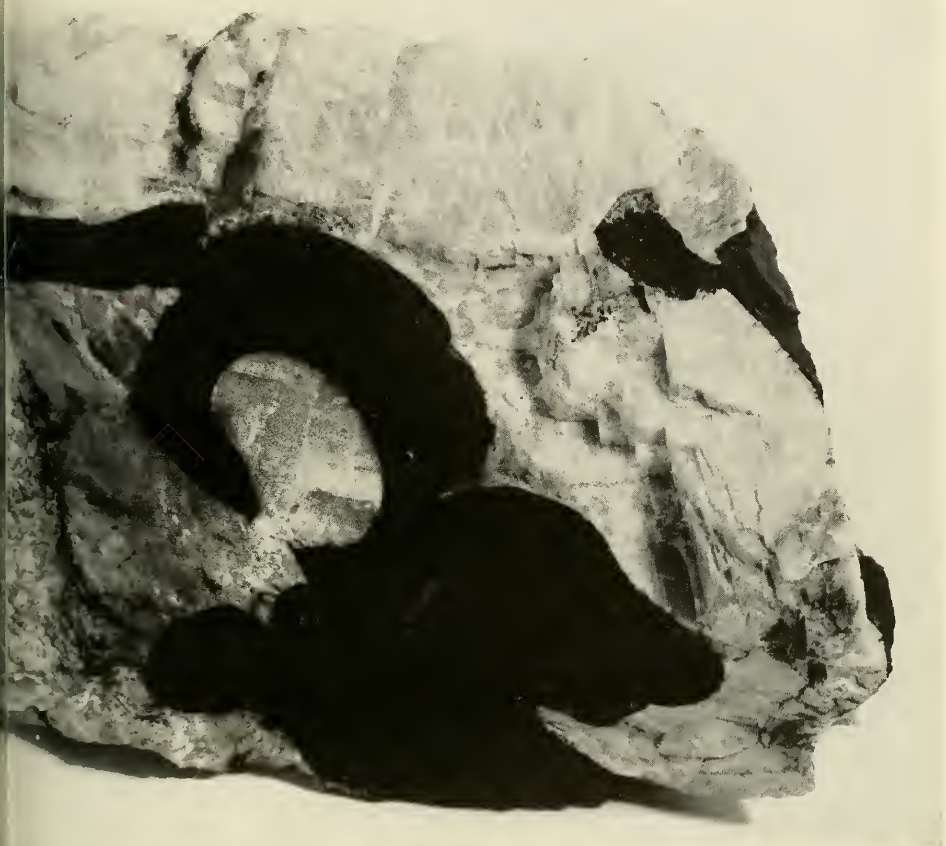
On the other hand, over the course of the past several hundreds of years, the mineral wealth won in a less spectacular way from the rocks of the eastern seaboard has been very substantial. For example, millions of dollars worth of gold have been taken from a narrow belt of terrain that parallels the east flank of the Appalachians, from Virginia to the rolling, red-earth country of north Georgia. (So productive was this "gold belt" during the earlier part of the past century that branches of the United States Mint were established in Charlotte, North Carolina, and Dahlonega, in north Georgia, for the minting of gold coins.)





A number of copper mining ventu
have flourished along or near the e
coast, from Vermont to Tennessee;
a variety of strategic minerals—f
spar, mica, beryl, asbestos, graph
tungsten, and others—have been mi
and quarried in the eastern states.

Foremost, however, among the imp
tant mineral properties of the east co
both historically and in point of mine
wealth produced, are the twin zinc pr
erties of Ogdensburg and Franklin,
New Jersey's Sussex County, a b
forty miles from the city of New Y
This world-renowned mining- and m
eral-collecting locality is near the he
waters of the placid Wallkill River
the highlands of northwestern New
sey. It lies within a complex assortm
of ancient and somber-hued gneis
quartzites, and metamorphosed li



ARK RED ZINCITE traces a bizarre pattern on its matrix highly crystalline Franklin limestone. This rare mineral is the oxide of zinc, often carries small amounts of other elements, and usually occurs as grains or compact masses.

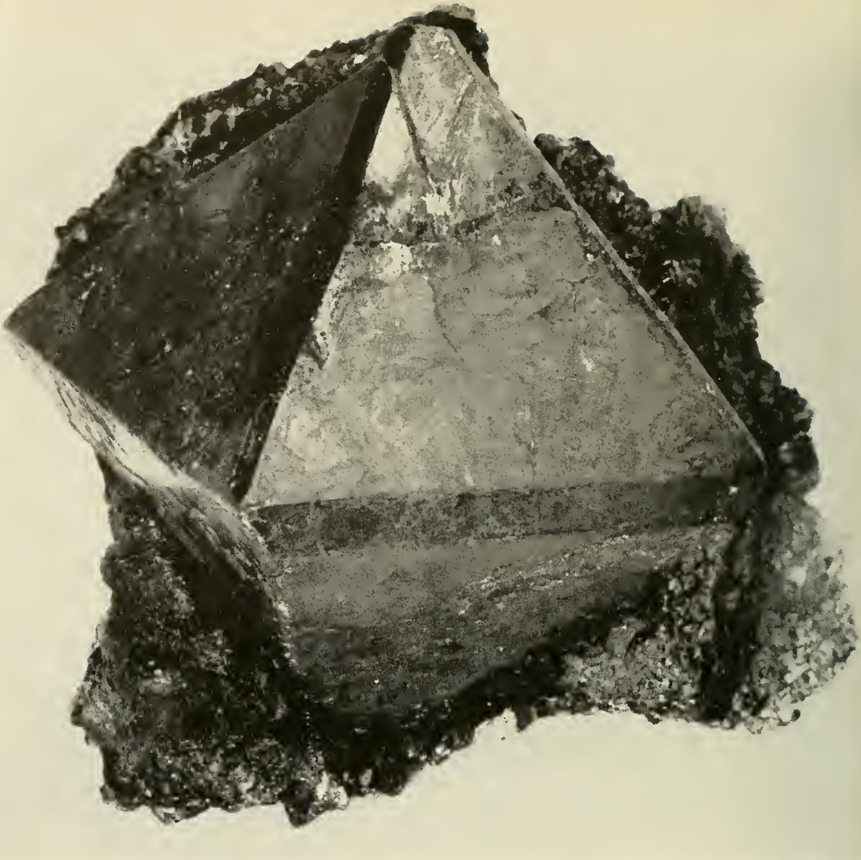
ones of pre-Cambrian age, which nerges from a cover of younger rocks the east and rolls gently westward toard the northern Appalachians. Here, und within the distorted and erosionly disconnected remnants of a crystalne limestone—the Franklin limestone are the strange, vertical, fishhook-like e bodies of Sterling Hill, in Ogdensrg, and Mine Hill, in Franklin, a bare ur miles apart. Closely related both ologically and mineralogically, the o mines have furnished mineral colctors and museums the world over with ore than a hundred catalogued varies of minerals, many that are great rities and a number that are unique. th the limestone and the ore are ought to be of similar age; on the sis of the radioactive-potassium ethod of determination, some billion and a quarter years are believed to have elapsed since their formation.

At both localities the principal ores are franklinite (an oxide of iron, zinc, and manganese); willemite (the silicate of zinc); and zincite (the oxide of zinc). These three minerals are of great collector interest in themselves, franklinite being nearly exclusive to the locality, while willemite and zincite are seldom encountered elsewhere in the mines of the world. In addition, the willemite and much of its calcite gangue, or matrix—and a number of the other minerals—are brilliantly fluorescent under the ultraviolet lamp.

As seen in the ordinary hand specimen, still available on the dumps of Mine Hill at Franklin, the minerals franklinite and willemite occur together as patches or "nests" in a matrix of sparkling white calcite. The franklinite is jet black, very closely resembling common magnetite. (It has, indeed, been classified merely as a zinc- and manganese-bearing variety of that mineral.) It has a hardness of 6 in the Mohs scale, and a specific gravity of 5.15, compared with the 5.18 of magnetite.

The typical octahedral pattern of crystallization of franklinite is rather obscured in the average hand specimen at either locality because of a uniform rounding and smoothing of the angles between crystal faces, perhaps as a result of partial absorption of the mineral by the calcite host rock.

The second zinc mineral, willemite, occurs with franklinite as a somewhat formless, rounding, glassy grain scattered about in loose aggregates on its



Franklinite is one of the primary minerals of the Sterling Hill and Franklin ore bodies. It is an oxide of iron, zinc, and manganese, and this striking specimen clearly exhibi the mineral's usual octahedral pattern of crystallizatio

matrix of crystalline calcite. It varies considerably in color, even in the same specimen, and may range from colorless through various pastel shades of green, and from pale buff and pale peach through shades of red and reddish brown. Willemite is nearly as hard as franklinite (5.5 on the Mohs scale) but hardly as heavy (specific gravity, 3.9 to 4.2, depending largely on the percentage replacement of the zinc component by manganese and possibly small percentages of iron and other elements).

The third, and by far the least common of the three major zinc ores of Franklin and Ogdensburg, is the rare mineral zincite, occurring as grains and "stringers" in mixtures of the first two minerals. Ordinarily an eye-catching blood-red in color—perhaps through contamination with manganese oxide or some other metallic oxide, since pure zinc oxide is white—zincite is the softest of the three principal minerals (Mohs scale 4), and has a specific gravity of about 5.5. The distribution of the three minerals at both mines has averaged, over the years, about 40 per cent franklinite, 23 per cent willemite, and less than 1 per cent zincite, the remaining material representing the silicates and carbonates of the gangue.

However, it is from this "remaining material," worthless and expensive to the mine operator, that a host of minerals has come to make the twin localities of Franklin and Ogdensburg bywords in the world of mineralogy. For most mineral collectors, these rarities must remain only names in the textbooks of mineralogy—names like roeblingite, barylite, nasonite, sarkinite, yeatmanite, and scores of others, mostly representing unusual or unique combinations of elements like arsenic, lead, barium, boron, beryllium, chlorine, or antimony with the silicate and carbonate components of the locality. Many mineral spe mens from these two mines are st awaiting professional investigation in their complex chemistry, and are as y unclassified and nameless.

The exact discovery dates of the t properties, rich historically as well mineralogically, have been lost in t haze of the intervening years. There some evidence that the ore outcroppin at Sterling Hill were noticed by 164 and perhaps even earlier; and that tho of Franklin were known before 17 (As a matter of interest, there is am evidence that the early colonists America were just as avid in their qu for mineral wealth as the gold- uranium-seekers of later times.)

Early records show that the first m ing operations in the vicinity were p marily directed toward iron productio and, since franklinite closely resemb magnetite (the common oxide of iro it is quite likely that the iron-found

Paul Mason Tilden, formerly an Editor of Nature Magazine and a rock and mineral collector himself, new continues his regular column in the pages of the combined magazines.

the vicinity tried to use it in conjunc- n with local and other iron ores. Ac- ally it was not until the spring of 1819 at the true identity of franklinite was ablished by the laboratory of the yal School of Mines in Paris. A paper Lardner Vanuxem and William Keat- g. read before the Academy of Natural iences in Philadelphia in 1822, at- ted to the mismarriage of these differ- g ores in the iron furnaces of Franklin.

"Having long attempted to work by e common process," noted the two rlier American men of science, "an e which was of a distinct nature, and ich, consequently, required a distinct de of treatment, they (the iron- kers) at last threw up in disgust an dertaking which with very little sci- ce would have been highly productive."

In any case, there was a sheriff's no- e of "public vendue," consisting of ne forge situated on a branch of the allkill (a never ending stream)" and laves, horses, oxen . . . pig and bar n, waggons," as well as many other ms common to early iron-founding.

It remained for one Samuel Fowler, a ctor of medicine and long-time resi- nt of the village of Franklin, to put the c ores of the locality to a practical e, even if in a rather modest way. Dr. wler, a member of the United States use of Representatives from 1833 to 37, was a practicing physician and a n of inquiring mind. He came into ssession of the Mine Hill zinc property ring the first decade of the nineteenth ntury, and his name is prominently nnected with early efforts to utilize complex zinc ores of Franklin and companion locality at Ogdensburg.

The year 1830 found Dr. Fowler pro- cing a "bluish-white powder" from the s. This he employed as a substitute white lead in painting his house, and is quite possible that this was the first e of zinc oxide from an American ne for such a purpose. Dr. Fowler be- me deeply engrossed in an effort to ce the treatment of the stubborn zinc s on a commercially profitable basis.

During Samuel Fowler's tenure as a S. Representative, Congress passed a authorizing the nation's first set of ndard weights and measures for use the government customs-houses. In 1838, the United States Arsenal in Washington produced the first metallic zinc ever made in this country. It came from "New Jersey red oxyde of zinc" furnished by Dr. Fowler from his Mine Hill property. The zinc was then alloyed with copper to produce the necessary brass for the new weights and measures, and the ore pit from whence came the particular "red oxyde"—now called zincite—became known in later years as the "Weights and Measures opening."

Throughout the earlier years, the innumerable small mine properties at Franklin and Ogdensburg seemed to be in constant financial and legal difficulties, and many were the failures, the sheriffs' sales, and the court wrangles over property boundaries. A guarantee of future litigation might have been read into the words of an early surveyor's report, in which, with a blissful disregard for the passing of the years, it was recorded in part that Sterling Hill included "all that parcel of land in the Province of East Jersey beginning at two ash trees marked on four sides with three notches, standing on the west side of Wallkill creek. . . ."

Samuel Fowler spent years in search of a practical method of separating and reducing the intimately mixed iron, zinc, and manganese ores of Mine and Sterling Hills. There was a vast fortune in base metals awaiting a fortuitous turn of the lock; but persistent Dr. Fowler was never to possess the key to the treasure house. Toward the middle of the century, Dr. Fowler died, and control of the properties passed, by way of Fowler's son, into the hands of a courageous group that titled themselves the "Sussex Zinc and Copper Mining and Manufacturing Company."

In 1852, this organization became the New Jersey Zinc Company, a mining corporation still extant; and a few years later, in 1865, a method was devised for producing metallic zinc from the refractory ores, although production was slow because of the difficulty encountered in separating the iron-laden franklinite from the willemite and zincite. Further experimentation led to the invention, in 1896, of an ore-dressing apparatus called the Wetherill magnetic separator, and at last the flood of metallic treasure commenced on the grand scale. The total wealth given up by these two mining properties, from first to last, is impossible to estimate exactly; but it runs into the hundreds of millions of dollars.

On February 13, 1961, Richard W. Westwood died in Washington, D. C. This internationally known nature educator was the former editor of Nature and a contributing editor of Natural History after the two publications merged. His loss is deeply felt both by his colleagues and his hosts of readers.

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of the Franklin and Sterling Hill d
deposits, the word unique is admissab
At these two localities, the element zi
occurs in great quantities as an oxide
a silicate, rather than as a sulphide;
mineralogical situation which, so far
known, is without a counterpart in t
world. The geological reason for su
an occurrence has yet to be fathome
despite the painstaking work of some
geology's most acute observers.

Nor is there agreement as to the mo
of formation of the ores. Some geo
gists assign a sedimentary origin
them, feeling that they were origina
deposited at the bottom of a pre-Ca
brian sea, along with the limy sedime
that were one day to be called the Fra
lin limestone. Other geologists think
the ore bodies as the highly metam
phosed products of magmatic, or molt
rock, action; yet others speculate t
the ores were deposited by high-te
perature waters and gases, deep bene
the earth's surface—the so-called
placement type of ore deposition. T
amateur student of geology and miner
ogy, studying the vast accumulation
fact, theory, and speculation develop
on the subject, will no douht sympath
with a one-time superintendent of t
mines at Franklin, who, on bei
queried about the geological history
the ores, replied, with more sincer
than elegance: "The origin of the or
am not so familiar with, as it has be
my misfortune to hear . . . a good ma
causes for this ore body being at Mi
Hill; I hardly know which to accept."

Today the underground treasure
Mine Hill is exhausted, the great p
silent, and the deep shafts filled w
water. For a small fee, visitors m
secure collecting privileges from t
Town of Franklin, and roam at will o
the vast dumps in search of the miner
that brought world-wide attention to t
locality. Sterling Hill, four miles aw
at Ogdensburg, is not open to the c
lector; it still possesses great reser
of zinc against a time of higher pric
or national need. In this latter villa
some of the local miners are wont to s
perhaps a bit wistfully, that the ores
Sterling Hill "will last forever."

This list details the photographer, art
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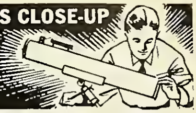

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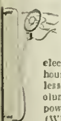

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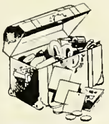

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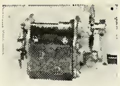

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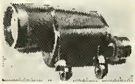

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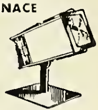

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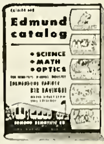

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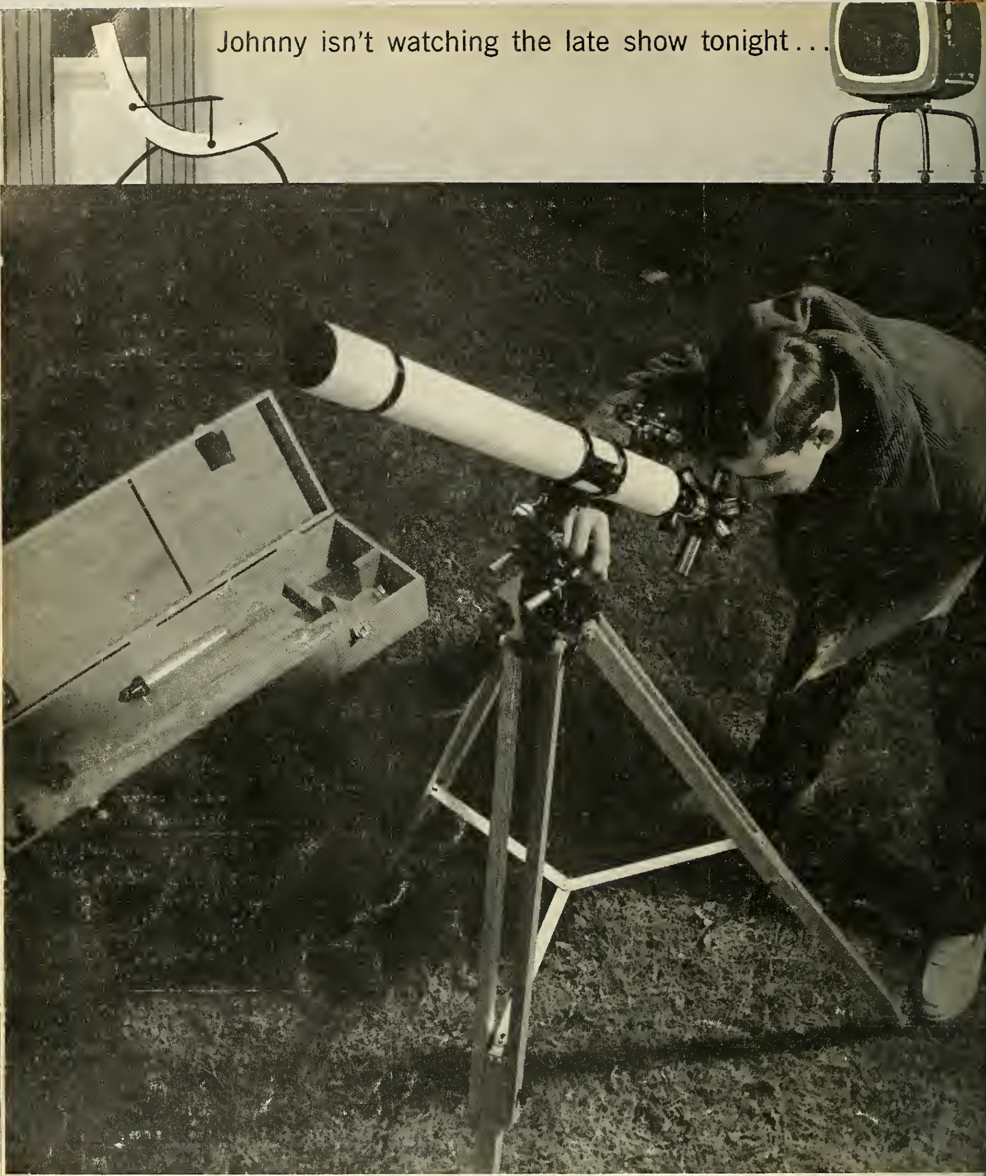

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Natural History

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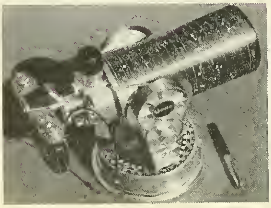

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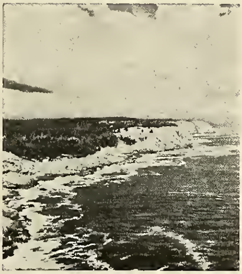
The Fortunate Island



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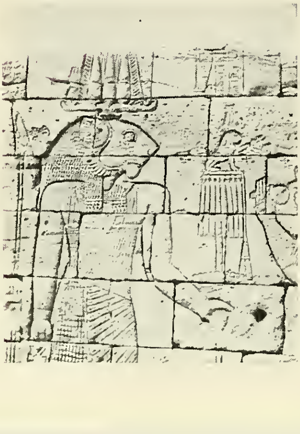
NATURALISTS' NOTEBOOK: A GREEN DARNER EMERGES
NATURE AND THE MICROSCOPE *Julian D. Corringto*



COVER: A wall carving in the Naqa Lion Temple in the Sudan shows Aped lion god, war god, and sun god of the ancient Meroites, in a pose suggest Egyptian imagery—his leonine head in profile, torso almost frontal. Th martial and celestial functions, he is thought to be associated with ironm as practiced by the Meroites. This view is supported by slag finds at a v of Meroitic sites, visited last summer by Hans Guggenheim, an artist and st of anthropology, whose work has appeared often in the pages of this mag His illustrated report on Meroitic ironwork and related finds starts on p

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e yourself journeying up the Missouri in the first the last century. What would you expect to encoun- t is difficult for most of us even to try to imagine ause of the thousands of changes that civilization ade in the last hundred years or so. What might een an uninhabited plain or a dense wood may now arm or even the main street of a town.

s only one reason why the journals of the beloved an naturalist, J. J. Audubon, grow even more valu- very day, not only to ornithologists, naturalists and of wildlife, but to anyone interested in the Ameri- ene. To read his Missouri journals, for example, is to travel again through the heartland of America when the land was practically uninhabited, when herds of buffalo thundered across the plain, and the sky was often blackened with huge flocks of birds; when the banks of rivers and streams were thick with elk, antelope, otter, beaver. To read his Labrador journals is to accompany the great naturalist on an exploring trip across the rock and moss bogs of the bleak northern lands.

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Review

The atmosphere and man's activiti

By Paul R. Ju

THE OCEAN OF AIR, by David I. Blumenstock. *Rutgers University Press, $6.75; 457 pp., illus.*

BY VIRTUE of gravitational attraction, the planet earth holds to itself a gaseous composition of nitrogen, oxygen, carbon dioxide, water vapor, and numerous trace gases. By weight, most of this gaseous envelope, which we call the atmosphere, is concentrated within a few miles of the earth's surface; at an altitude of approximately 18,000 feet, one-half of the atmosphere lies below, while two-thirds of it lies below the 29,028-foot summit of Mount Everest.

In its daily rotation, the earth intercepts a prodigious amount of radiant energy from the sun. Some of this energy is reflected back to space; a small amount is absorbed by the gaseous envelope itself, and the remainder is absorbed by the surface of the planet. This absorbed energy represents the energy source for the motions of the atmosphere on all scales. The geometry of the earth's annual orbit and the composition of its atmosphere are such that the equatorial regions receive more heat from the sun in the course of a year than they are able to return to space. In polar regions, on the other hand, the earth and atmosphere radiate more heat than they receive. Thus, the atmosphere, in constantly adjusting this energy imbalance, is caused to move and large-scale wind systems result. This circulation of air on a hemispheric scale is called the general circulation of the atmosphere, and it reveals a number of characteristic wind patterns, such as the easterly trade winds that blow with monotonous regularity over the subtropics.

Above the first few thousand feet of the earth's atmosphere, the winds become stronger. Over most of the earth—roughly from latitudes 30° north and south to the Equator—the winds above the surface layer and below 30,000 feet are easterly. Above the remainder of the earth, the winds at these altitudes are westerly. Such winds are integral parts of the large-scale weather systems known by various names: extratropical cyclones, hurricanes, anticyclones, monsoons, easterly waves, and so on.

These weather systems are a form of turbulence—large-scale eddies in the planetary circulation of the atmosphere. Thus, the easterlies and the westerlies lying above the surface layers ex large, wavelike oscillations that c the winds to deviate on a daily, we or monthly basis from their usual c tion. The usual behavior of these v accounts for the climate of a parti area: the large anticyclones of the tropics, for instance, produce the n arid regions of the earth, while "roaring forties" (or middle latitu are influenced by the extratropica clones of the westerlies, which pro an invigorating climate of large ter ature changes and generally adeq moisture. It is in this belt that mo the earth's humans reside.

Amidst—or, rather, at the botto —these planetary winds, man wo at the power, the complexity, an vagaries of the atmosphere's beha A host of terrifying or beautiful, eficial or disastrous, expected or pected events take place as occurrences within these broad wind circulations. Clouds, precipit drought, hurricanes, tornadoes, zards, floods, and so on are all wh term, collectively, "the weather." also part of atmospheric phenomen such things as auroras, meteors, r tion of radio waves beyond the ho fluctuations of the earth's mag field, the blue of a cloudless sky many other invisible phenomena are less familiar to the non-scienti

ANY successful attempt to wr comprehensive survey of th mosphere, including all its pheno its structure and its effects on would be an accomplishment in David Blumenstock has written a lengthy book, whose subject, mos ticularly, is this ocean of air physical order, its observation an ceptibility to prediction, and its re to man. Of necessity, some subjec omitted or touched upon only br the immensity of the field imposes a treatment. *The Ocean of Air* is, ever, a comprehensive, non-tec survey of the atmosphere, which w terest everyone, including the p sional meteorologist.

Blumenstock's emphasis is heav weather and climate in relation to activities, and on the economic an toric aspects of the atmosphere in ately enveloping us—the troposp that portion wherein man has lived, raised food, fought battles, and built civilizations, and where the weather that influences all his activities occurs. The author, however, included material on the upper atmosphere—that region above the level of five to ten miles' altitude where weather as we usually think of it does not occur, but where we do find such phenomena as auroras, meteors and magnetic storms. Even the outermost reaches of the earth's gaseous envelope receive mention: the Van Allen radiation belts and the playgrounds of cosmic rays.

Because until recently no real science of the lower atmosphere existed and no observational data were to be had from the atmosphere above this lower portion, little interest was shown in the upper reaches of the atmosphere aside from philosophical speculation. Today, with the emphasis on high-altitude aircraft, space technology, and nuclear weapon testing, these regions above the troposphere are receiving intensive scientific investigation. The modern science of the atmosphere must be said to include the study of these regions and phenomena as well as the processes of the troposphere, which lies below them.

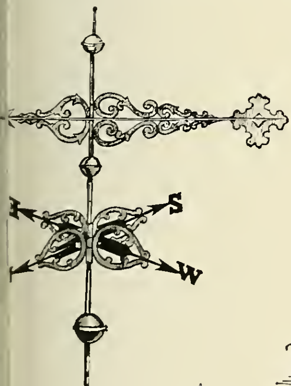
DR. JULIAN is on the staff at the High Altitude Observatory of the University of Colorado, at Climax.

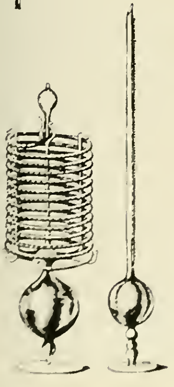
But here we encounter a confusion of definitions. By virtue of long, historical usage, the science of the entire atmosphere is called meteorology. However, it now seems that more clear-cut definitions are needed because of the many almost independent disciplines studying various portions and phenomena of the atmosphere. Geomagneticians, ionospheric physicists, and even aeronomers—a term applied to students of the very high atmosphere, where processes resulting from absorbed solar radiation are dominant—each of these, and many more, is generally conceded his separate discipline.

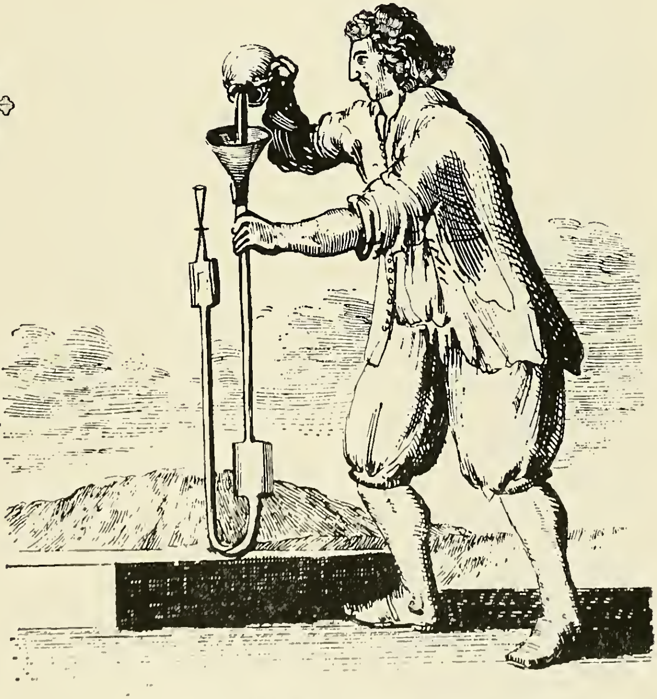
As a complicating factor, there has been a tendency, deplored by many atmospheric scientists, to divorce physics from weather forecasting. There are, for example, some authorities in such fields as the physics of precipitation or the physics of atmospheric electricity who consider a meteorologist to be a mere weather forecaster, and who consequently do not consider themselves to be meteorologists.

Just what the term "meteorologist" is supposed to mean today is somewhat cloudy, if such a timid pun may be allowed. Perhaps the term should be reserved for students of the general circulation of the portion of the atmosphere, that produces weather, as well as of the prediction of the general circulation and weather-producing mechanisms. Blumenstock's topic, at any rate, is meteorology in this sense, together with the long-term integration of weather processes known as climatology.

APART of all this semantic confusion is due to the historical development of a technology of weather forecasting. Such a technology was the result of overwhelming demands by society for practical results from a science that was still young, but which could make useful







KEY INSTRUMENTS for meteorological studies—the weather vane, *upper left*, thermometers, *lower left*, and the barometer, *right*—had been developed by the middle of the seventeenth century.

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short-range forecasts on the basis of quasi-scientific rules of thumb and could also make useful studies of aggregates of observed, historical data. Today, a large segment of the public confuses the technology with the science, and many atmospheric physicists are unfairly subjected to frequent, tired jests concerning future weather conditions and their inability to foretell them.

Now, the science of the atmosphere as it is concerned with weather forecasting is a unique science. It does not concern itself with scientific inventions, or with the control of natural phenomena, but with prediction. In few other sciences are future conditions the primary concern of the popular interest. Indeed, weather forecasting—as practiced—can hardly be called an exact science. As Blumenstock points out, experience, temperament, an ability to weigh many subjective factors simultaneously, and even, apparently, intuition are all attributes of a good weather forecaster. In my opinion, the dependence on such men has made forecasting essentially a craft or art, rather than a science. Such an approach was and is essentially a sterile one: no efficient method can be developed to accumulate, transmit, and digest, in a short period of time, the vast body of technical information acquired by experience and applied by intuition. Thus, for example, college graduates in meteorology, despite their having had the benefit of a scientific education, are of limited use as forecasters.

It is regrettable that Blumenstock did not choose to follow this matter further than he has, since it involves some questions of very general import, as well as some of the most interesting current problems in forecasting. Since the early pioneers in meteorology began studying the physical processes by which the atmosphere gains, transforms, and loses energy, and describing the manner in which the atmosphere actually behaves, man has gained a good understanding of weather-making processes. But the technology of prediction has failed to keep pace: our ability to predict has not improved appreciably over the last few decades. This dilemma compels us to ask what we may ultimately expect from a science concerned with prediction.

In the last ten years or so, numerical computers have made possible a rapid advance in techniques of prediction by means of mathematical equations; these are formulated so as to describe "model" atmospheres, resembling the actual atmosphere to greater or lesser degrees. Success with these techniques—to which Blumenstock devotes only a page—has been encouraging; already, the forecasts they have led to are comparable to those made by the method of experience and intuition. But it is obvious that to forecast accurately beyond a month or so, the model atmosphere must rese
the true atmosphere more closely th
now does. For this, for instance, we
know the effects of extraterrestrial i
ences, and we need to take into acc
the circulation of the oceans, a sy
complementary to the atmosphere'

But, even if it were possible to sp
all the variables known or though
have effects on the circulation of th
mosphere, could we then predict
weather a year in advance with suffi
accuracy to satisfy the farmer, the
lic utility companies, the airlines,
the housewife? Is the atmospher
other words, a deterministic system
able of being described in detail
or months in advance?

There is no doubt that the atmos
obeys physical laws, but the que
raised by the present "plateau of
dictability" is whether man will ev
able to cope with the complexity of
physical laws and the immense nu
of observations we need if we are t
these laws to predict future states o
atmosphere precisely enough to s
agriculture, commerce, and indu
This is a fundamental question, a
needs consideration both by the p
as consumers of weather forecasts
by the scientists, who must decid
most fruitful lines of research.

Today, the Weather Bureau and
private meteorological research or
zations are experimenting with fore
couched in probability terms. The
very good evidence that a proba
statement issued with a forecast c
of considerable use to the industri
commercial user of weather inf
tion. The general public, however
be slow to accept such forecasts.

THE author includes some pert
material bearing on the role
played by the atmosphere in man
tempts to meet problems of the f
one of which is the supply of
water. For mankind, water is
most important constituent of th
mosphere, and the hydrological c
precipitation, runoff, evaporation
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esses that, man has realized, c
made to work for his benefit. Our
needs for water point toward the in
ing importance of the precipi
mechanism of the atmosphere,
greater future almost certainly l
the conversion of saline water,
author himself suggests.

Problems of the management
water resources are receiving re
attention, both scientific and pol
at the present time. In the book, t
tricate interweaving of political,
and economic interests in the p
struggle for water in many river
is exemplified by the Delaware
An instance more familiar to th

er and to the West is the Colorado n. The bitter conflicts of interest cal of both areas are bound to be re- ed elsewhere in the future.

oreover, with the exceedingly rapid th of metropolitan complexes, water lems have begun to appear even in y places where rainfall is abundant. many of the present situations are idy outside the sphere of the atmos- ic scientist. However—as Blumen- k may be saying between the lines ould man exhibit the forethought of h he is capable in planning the e-scale expansion of his civiliza- , climatologists and meteorologists be ready to assist.

e topic of weather control—also inly related to man's future—is re- ng publicity today that, while equal s potential importance, is greater, rtunately, than its present scientific e. Interest has been aroused in the ect because of man's ability to mod- cloud structure and apparently, on sion, to increase precipitation. A plete history of efforts along these and of the modern revival of rain- ing, alone, would require a volume size of Blumenstock's whole book. nonetheless devotes a chapter to (pre-World War II) efforts to in- rainfall, to a brief discussion of efforts, and to a review of the final rt of the President's Advisory Com- e on Weather Control. He correctly that the Eisenhower administra- established the Committee because e confusion of claims and counter- ns that had been made. But he omits reference to the most controversial of the story. This is a pity, for was a prime example of technolog- and commercial interests "apply- the results of scientific endeavor naturely, because of the potential omic gains to be realized. The con- ent uproar—legal, political, and ntific—has not yet subsided. Re- ible meteorologists would agree, I k, that the whole affair has effec- y brought before the public many tions concerning man's efforts and ties to modify the weather, but out sufficient scientific evidence to le any answers to be given.

nce Blumenstock's book was writ- we have been able to read about tional proposals—including a $17 on scheme by a Russian to construct m across the Bering Strait and so r the climate of the entire Arctic. proposals are encouraging in that show that man's imagination has none of its vigor, but their scientific remains debatable. In any case, have no evidence that modest efforts ld ever suffice to modify large-scale her situations. On the contrary the ent knowledge of the atmosphere ests that only the fantastic efforts would be successful. Blumenstock sums it up most aptly when he says, "Control of the weather is not an impossibility; it is an impracticability."

ANOTHER contemporary problem in which the circulation of the atmosphere plays an important role is that of nuclear testing. Blumenstock gives considerable space to nuclear weapons, clearly explaining how the fallout problem and the question of the life of radioactive debris in the atmosphere involve atmospheric circulations of both local and hemispheric magnitude. Incidental to the observation and tracing of explosion products, meteorologists have been handed an excellent tool for the investigation of the general circulation of the stratosphere. Lack of hemisphere-wide balloon observing stations and the difficulties encountered in making routine observations at great heights have heretofore hampered our efforts to learn how hemispheric winds behave in the stratosphere—the region roughly from six to thirty miles above the earth.

Man's ability to create problems by his population concentrations also involves the atmosphere—or at least the debris he injects into it. Almost all large metropolitan areas today have a smog problem, although few are willing to admit it: only when the situation becomes so serious as to cause respiratory illnesses and other pathological effects is serious attention drawn to the matter. Solutions to the problems of air pollution do not lie with the atmospheric scientists, since not much can be done to change the atmospheric conditions that aggravate pollution. Atmospheric scientists can, however, determine the future danger zones and advise on precautions.

Man in the atmosphere about him is the recurring theme of *The Ocean of Air*. Climate and weather; their relations to economic, political, and social factors; and their influence on the growth of civilizations and man's future occupy the major portion of the book. The reader will not find physical explanations or detailed descriptions of atmospheric processes and phenomena. Rather, the author's brief discussion of the different layers of the atmosphere and of the winds and climates of the globe gives the reader the information needed to grasp their effects on man.

The book could hardly be called, then, scientific popularization in the style of Gamow or the Leibers. Another reviewer has compared it with Rachel Carson's *The Sea Around Us*, and Blumenstock's approach to the subject matter (and to a certain degree his style) do resemble Miss Carson's. The two books are in the same vein; they concentrate not on the technical details, but on the aesthetics of the subject, and they are written not as scientific textbooks but as literature.

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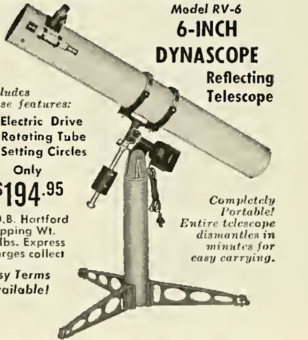

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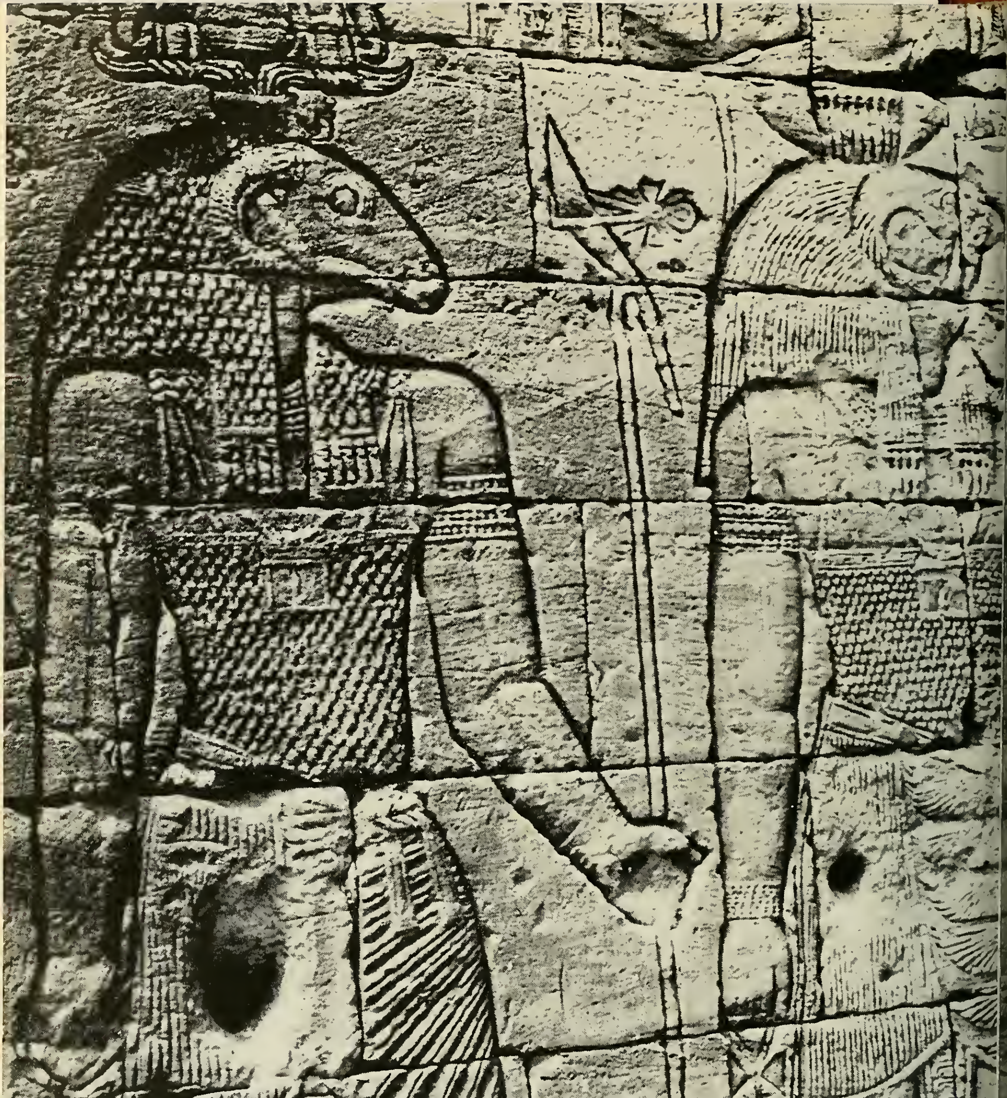
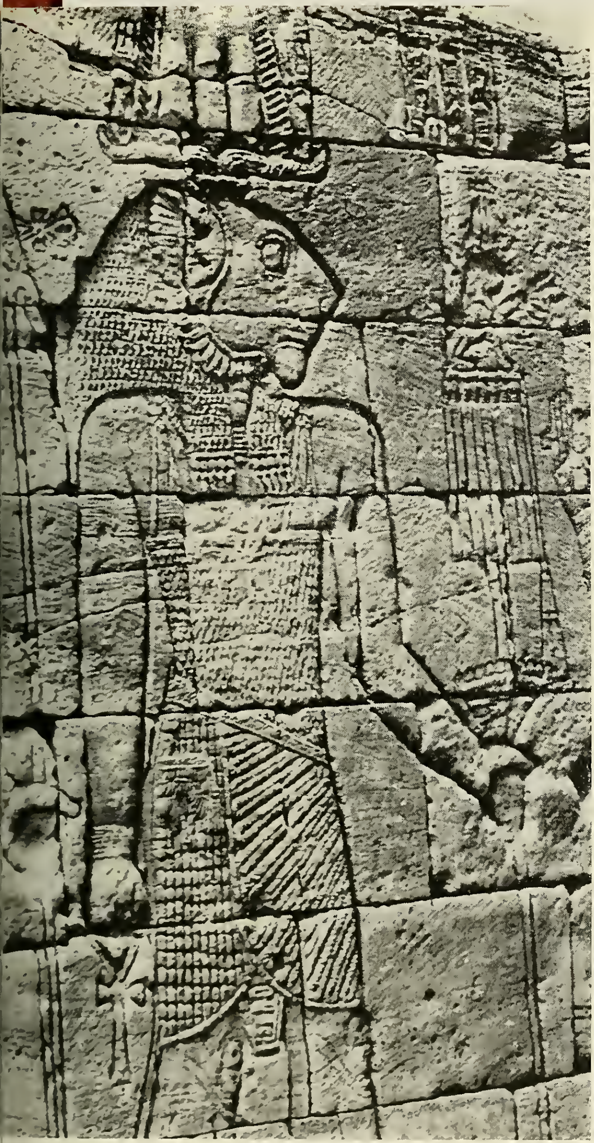


Smiths of the Suda

In Meroë, ancient capital of Nubia, iron smelting flourished

By Hans Guggenheim



Procession of gods, led by Apedemak, the lion god, is graven on the stone wall of a Lion Temple in the Sudan.

I THE NORTH of the Republic of the Sudan, where the Nile and the At- a rivers form a triangle, lie the s of Meroë, once the capital of the led kingdom of Kush. This is the t of the land known to the Egyp- s of ancient times as Nubia. From time of the Old Kingdom onward, pt controlled these lands stretch- n south along the Nile. Fortresses trading posts were built at Buhen, and at Semna and Kumma, to foster trade and protect the gold mines of Nubia. From Thebes, the high priests of Ammon ruled the Nubian area as viceroys, and the region was called "The Gold Lands of Ammon."

With the weakening of Egyptian power toward the end of the New Kingdom (*ca.* 1100 B.C.), Libyan warrior clans began to settle along vast stretches of the Nile. By the middle of the eighth century B.C., a fully developed Nubian Kingdom emerged, with a population composed of Libyan invaders, political refugees from Thebes, and local Negro tribes. These people came to be known to history as the "Ethiopians." Their capital was at Napata (map, p. 10), just below the fourth cataract, and Meroë was their main provincial city. Under vigorous leaders, these southerners pushed north to the conquest of Egypt, itself, and established themselves on the throne of the Pharoahs as the Twenty-fifth (or Ethiopian) Dynasty in 712 B.C.

While ruling in Egypt, the Ethiopians began to expand their original capital of Napata, constructing pyramids for their burials and creating there a civilization that, while Egyptianized, was not without a good deal of distinctive local color. By 662 B.C., however, the Assyrians—who had been threatening Egypt for some time—captured Thebes and forced the retreat of the Ethiopians back to Napata.

SOMETIME between 538 B.C. and 480 B.C., the Ethiopian kings shifted their seat of government from Napata to Meroë. The exact date for the shift has been difficult to establish, for the early rulers at Meroë still continued to be entombed in the sacred burial sites of the earlier capital. The reasons for the transfer of the capital —whatever the date—were complex. Military considerations may have played a part—Meroë was farther removed from the threat of attack from the north. The steady decline of trade with Egypt may have been another factor. Also, the Ethiopians were cattle raisers, as we know from the numerous cattle sacrifices found in their burials. If Pliny is to be trusted, there was probably more verdure round Meroë than in the more arid region of Napata. But if not the actual reason for the original transfer, certainly the most important factor for the subsequent flowering of Meroë must have been the gradual growth of an extensive iron-smelting industry.

Such an occupation would depend not only on available ores (which were present at both Napata and Meroë) but also even more on the existence of hardwood to provide charcoal for fuel. Of this timber there is still a supply round Meroë—in the form of extensive forests of sunt, a low-growing acacia that covers wide stretches of the landscape. Pliny's description—in his *Natural History*—provides a good picture of the region as much of it still is today: "In the vicinity of Meroë, greener herbage begins . . . a certain amount of forest comes into view, and the tracks of rhinoceros and elephant can be seen."

As to ore, on top of the sandstone of the Nubian plains, a surface crust of ferricretes may be found in layers a few inches thick. In the isolated hills of the region, these ferricretes appear as fairly large blocks, with a peculiar surface of glistening black nodules. Ferricretes seem to be caused by the action of small quantities of moisture that have brought iron, from extensive ferruginous deposits underground, to the surface. The iron ore, of an oölitic nature, runs some 70 per cent ferric oxide, equivalent to nearly 50 per cent metallic ore.

Such a combination of available hardwood and easily accessible iron ore seems to have enabled the old, cattle-raising kingdom of Kush to transform itself into a sort of small industrial empire at some time during the first century B.C. By that time, as a large smelting operation sprang up round Meroë, an astonishing change must have come over the Nubian scene. The smoke of the furnaces can be imagined as rising night and day: indeed, one English writer has compared the Meroë of that time to the industrial Birmingham of England's nineteenth century.

The evidence for all this activity is still visible at Meroë in the form of enormous slag heaps that surround the ruins of the capital. One of these was large enough to have been used as the base for a temple of Apedemak, the lion god. Another slag pile had to be cut through to allow the modern railway line to pass the site: it was found to be solid slag, twelve feet deep. Regarding this first century B.C. Birmingham of the Sudan, three q tions exist, all riddles to which we give only speculative answers:

First, how and when did the Et pians learn to make iron?

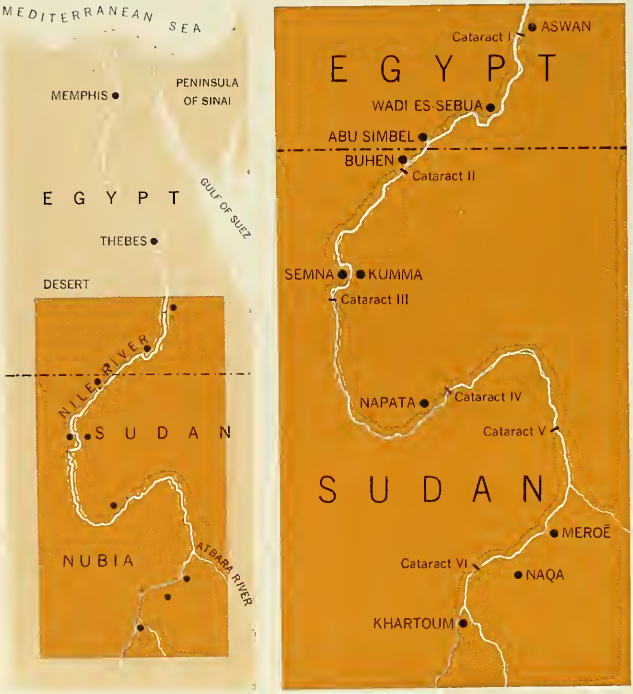
Second, what did they fabri from their finished iron?

Finally, how was the ore work

As to the first question, some kn edge of iron existed in Egypt as back as 3500 B.C. But only meteo iron was worked at that time: ind such iron was later known as *bia pet* (marvel from heaven). The th derbolt was thought to be of iron, so were the bones of the Egyp storm god, Set. Small knives mad iron have been found at that dei "thunderbolt city," Cetopolis, d to 2600 B.C. They belonged to Um the high priest and "opener of mouth of the dead," a ritual thou necessary to enable the dead to the food provided for them in t tombs. It was thought that only —which came from the heavens— the magical properties required to form this sacred function.

Very few finds of Eg dating to the next 1.500 been verified and accepted by ars. They include the followi Fourth Dynasty piece, from Cheops pyramid (possibly of meteoritic origin); a Fifth Dy chisel, from Saqqara; a Sixth Dy pickax from Abusir together some similarly dated tools f Dashur; and some iron rust Abydos. A supposedly Twelfth nasty Nubian spearhead (a piece, too good to be true) resem modern Nubian spearheads.

By the Eighteenth Dynasty, an vessel was received as tr from "Tinay," an undefined re north of Egypt, by Thutmose III. ters mention gifts to Amenhote of this same dynasty, from Tu King of Mitanni (a land in Minor); one steel-bladed dagger mitten of iron overlaid with gold two rings of iron. A "sacred ey iron mounted on a gold bracele longing to the Twenty-second nasty, has also been found, as clumsily made, miniature hea But it has been concluded by Wainwright, (*Sudan Notes and ords, Vol. XXVI*) one of the fore students of Meroitic iron, that a as the Twenty-fifth Dynasty—t to say, the time of arrival of the

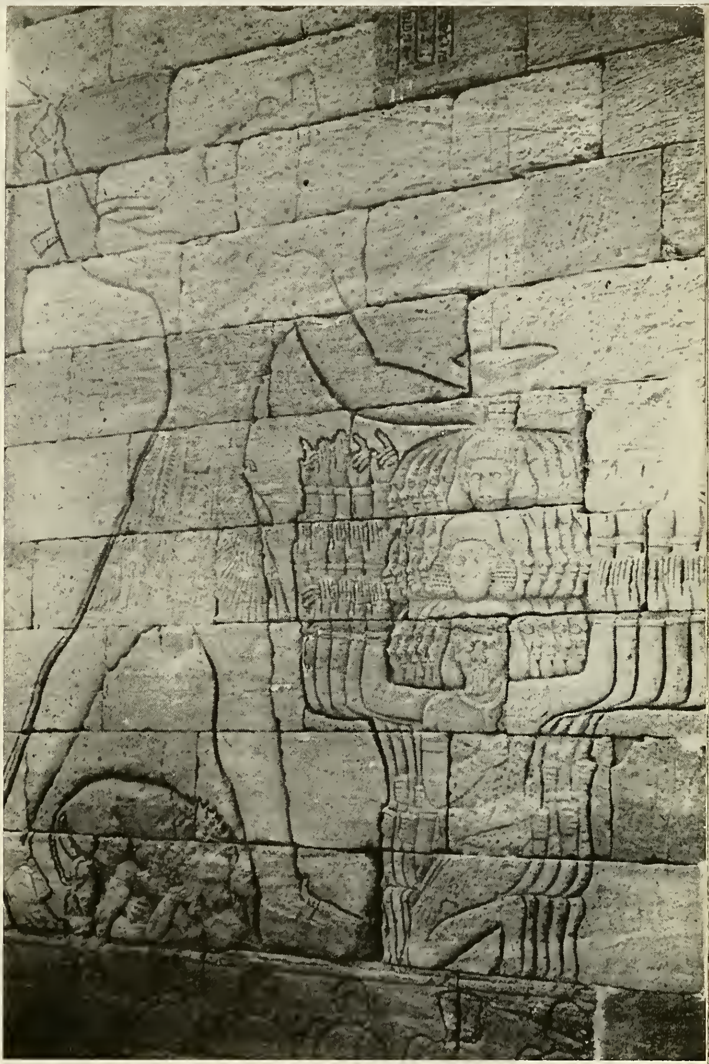


Northern Sudan, bordering on Egypt, is shown, at right, in an enlargement of darkened area on map at left. Region was once heart of the Nubian Kingdom.

ans in Egypt—iron smelting and working were still in their infancy. his contrasts sharply with the situ- n in Asia Minor. There. iron was w ked successfully by the Hittites: the eleventh century B.C. much of Near East was in a full Iron Age. the second half of the eighth centu, Sargon II of Assyria already had tons of iron ingots stored at his pace in Khorsabad (742-705 B.C.), an iron was common enough to be w ked into chains for prisoners. The ar Eastern knowledge of iron w pons may have been one of the sons why Egypt was unable to w stand the pressure of the Assyri- n. The Assyrians spoke of the Nile pire with contempt, and there is no ition of iron in the meticulous rec- s of the booty taken at Memphis a Thebes when the Assyrians fi- ny succeeded in expelling the Ethio- pin Dynasty from Egypt.

WHAT. then, about a knowledge of iron among the Ethiopians of ? In 654 B.C., a new ruler— -gained power in Egypt, g the Assyrians with the rian and Ionian mercenar- nt to him by Cyges, the King of a, who was trying to gain Egypt's ndship against Ninevah. These ians and Carians were iron-users: P mtik II, trying to re-establish ptian hegemony over the lower an in 593 B.C., led an army of e people (including Phoenicians) far south as Abu Simbel and en, where they seem to have set- tl down. Until 525 B.C., succeeding es of these mercenaries appear to e entered Nubia. It is possible that th may have introduced the Ethio- ns to the knowledge of iron tools weapons, if not to the actual tech- es of ironworking.

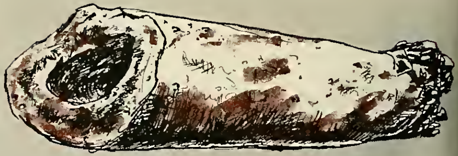
till another group of iron-using ors to the Nile were the Persians er Cambyses, who gained control Egypt in 525 B.C. Although no eological proof for his presence ubia has been found. Cambyses' e is linked in many ways to oë. Diodorus says that Cambyses ded Meroë and named it after his her. Josephus (A.D. 93?), claims Cambyses named the city after sister; and Strabo says that the ueror's wife died there. These ies are probably apocryphal. but at this date, the Ethiopians seem ave been without iron, for Herodotus says: ". . . their arrows were tipped not with iron, but with sharpened stone. the stone with which seals are carved; and they had spears pointed with gazelle's horn sharpened like a lance."



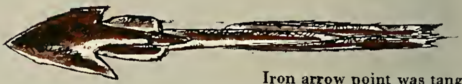
MEROITIC KING is shown on a wall of Lion Temple as he triumphs over foes. Multi-outlined representation of the vanquished is distinctly non-Egyptian.

No iron has been found in the royal tombs of Napata from the time of the oldest. that of Kashta (750-744 B.C.), down to Harsiotef. who ruled from 342-328 B.C. The same is true of the foundation deposits of the temples of Taharka and Shabaka. Indeed, it has been asserted that. in the great days of the Ethiopian Empire, their kings were as much in the Bronze Age as was the whole of Egypt.

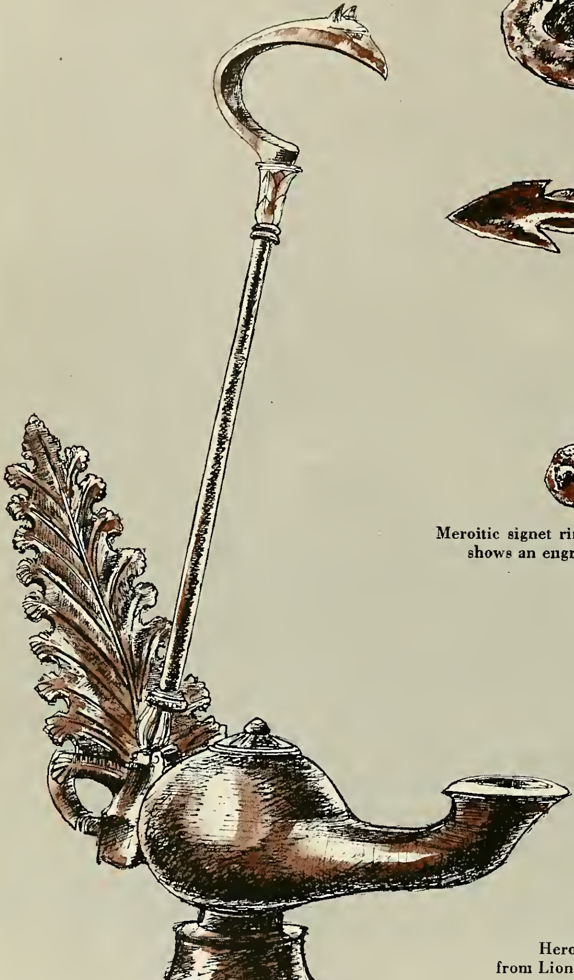
It may be concluded that the knowledge of ready-made iron was brought to the Ethiopians by iron-using foreigners from the north. Possibly, some knowledge of iron smelting also diffused southward to Nubia via Egyptian craftsmen who might have learned the secret from the same sources. But it is not at all inconceiv-



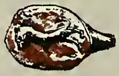
Tuyère, a clay pipe, helped provide furnace draft.



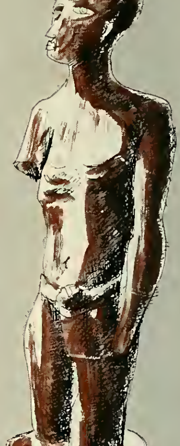
Iron arrow point was tanged to fit into wooden shaft.



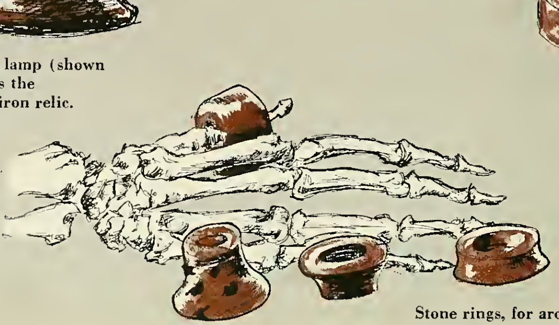
Rod for hanging lamp (shown in restoration) is the largest Meroitic iron relic.



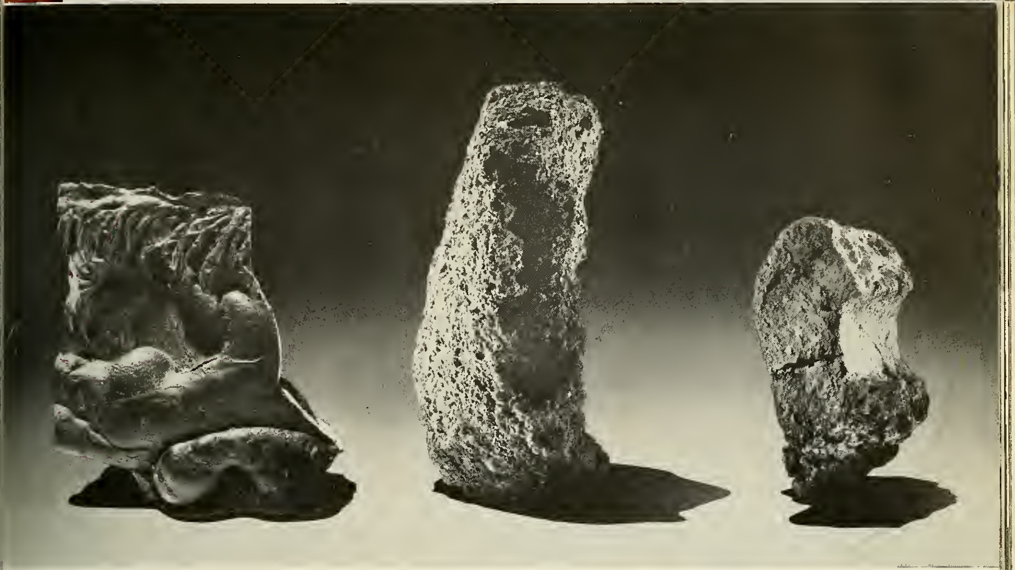
Meroitic signet ring of iron shows an engraved lion.



Heroic figure, of wood, from Lion Temple at Meroë.



Stone rings, for archers, are another Meroitic find.



RFACE FINDS at Meroë include such evidences of former on metallurgy as the three shown here. At left is a lump of iron slag; at center, a fragment of a clay furnace wall; at right, a portion of a tuyère to which slag still adheres.

le that native genius, stimulated by on objects in hand and familiar with ence and bronze metallurgy, sim- made use of the local raw materials d reinvented the process.

When it was that iron smelting at eroë took on its apparent immense portions we do not know, but there ists evidence to establish the basis an estimate. We have already ntioned the Lion Temple of Ape- mak, erected on a slag heap at eroë. This temple has been dated to first half of the first century B.C. the basis of an inscribed stele. We presumably date the beginning of n smelting backward from that nt, at least for as long as it would ve taken to accumulate the mound slag on which the temple rests.

ONE cannot assume that the temple was built on this slag heap by cident. Apedemak, the lion god and etical rival of the Egyptian Osiris, s thought to be the god of war in bia. As such, his connection with n is quite understandable, not only ause iron represented strength, t also because of the ancient rela- nship of iron with the sky. It is teworthy that one of the very few roitic iron rings found bears an en- ving of the lion god. Aside from Lion Temple at Meroë, there exist number of other shrines to Ape- nak, including a beautifully orna- nted one at ore-rich Naqa.

It is thus conceivable that the slag heap on which the temple rests at Meroë was built up somewhat deliberately to create a fitting base for this edifice, and that this was accomplished in a relatively short time. Under these circumstances, it is best to date the beginning of the slag heap conservatively at not much in advance of 150 B.C. and no later than 50 B.C.

Our second question was: what did the Ethiopians do with their iron? For all the enormous amount of smelting that went on at Meroë, little has been found by which to measure this Sudanese Birmingham's productivity. Because of imperfect methods, the loss of iron in the slag was shocking, even by primitive standards. But it must still be supposed that the kings of Meroë were well-supplied with iron and that when ironworking was first established it probably operated as a royal monopoly, or perhaps a priestly one. It is even conceivable that the ancient kings encouraged a concept of uncleanliness and impurity in connection with ironworking, perhaps to keep the process secret. Many of the superstitions and beliefs about iron found among present-day primitive African societies are at least suggestive in this respect.

No graves of the common people have been found that fall in the early period of the Meroitic Kingdom (538 B.C.). The earliest find of Meroitic iron is part of the hotly contested Ferlini treasure, allegedly found in the pyramid of Queen Amanshakete (45 to 15 B.C.). Among the objects purportedly from this pyramid are a pair of shears, a broken chisel, three spoons, and three needles, all iron.

Iron objects, at this time, are mainly confined to cosmetic articles. However, a skeleton dated *ca.* 25 B.C. bore an iron arrowhead between the shoulder blades (presumably the cause of death). After that date, arrowheads of iron seem to have increased rapidly. In tomb W 122 at Meroë, which is dated A.D. 150 to 300, the Boston-Harvard expeditions of the 1920's found a quiver containing seventy-three iron-tipped arrows.

After that date, all Meroitic cemeteries that have been dug contain iron objects—with arrowheads in the increase—until the second and third centuries A.D., when iron arrowheads suddenly cease. Even in these later years, however, the number of iron-containing graves is still very small in relation to the total number. At the Farras cemetery, only 107 of 613 recorded graves held iron, while at some of the poorer cemeteries, such as Karanog, the ratio was only 68 graves containing iron to 783 excavated.

BY the fourth century A.D., however, the rarity of iron seems to have diminished: expendable arrowheads were manufactured in greatly increasing quantities. These, as well as agricultural implements such as hoes, may easily have served a double function—as objects useful in themselves and also as a medium of exchange—and may have played a part in the not inconsiderable Nubian trade with Egypt. We know no details, however, of how this trade was effected. Through Egypt, there had been considerable contact between Nubia and the Roman world: indeed, Napata was destroyed in 23 B.C. by Gaius Petronius, although Meroë seems not to have been affected by this event. Roman cultural influence led to the creation of strange mixtures of ideas. In the third century A.D. Meroitic tomb W 122 [already mentioned], next to the quiver with the seventy-three arrowheads, was found an oil lamp associated with traces of the largest single piece of Meroitic iron that has been discovered. It was a diagonal rod connecting the bronze head of a bird with a base from which emerges a large acanthus leaf (illustration, p. 12). The oil lamp. itself, was of Meroitic manufacture. These lamps can be linked with a tradition in lamps of funerary character that ranges from Rome through Egypt to the Far East: the bird symbolizes the sun, the tree (in this case represented by the leaf), the "cosmic tree" or "tree of life." The use of a valuable iron rod in the assembly of the lamp becomes understandable again if we bear in mind the supposedly magical properties of the metal.

To sum up, a sharp discrepancy exists between evidence for major iron production at Meroë and evidence for end-use of the metal. The grave objects found do not begin to account for the supposed industrial output, even though arrowheads are common after 25 B.C. and the value of iron thereafter seems to have decreased. One possible explanation of this gap between presumed output and the finds is that the concept of uncleanliness associated with iron may have made iron objects unpopular as grave furnishings for commoners.

Our final question was: how was the iron worked at Meroë? The ore found in that region is. as we have seen, mostly oölitic—with a great many impurities—including silicon, alumina, sulphur, phosphorus, manganese, and carbon. It is suitable for reduction in the sorts of smelters—called bloomeries—that existed at Meroë. To gain metallic iron, it is necessary to reduce the oxide by adding carbon in some form, such as charcoal. The ore is mixed directly with the fuel and the mixture must reach a temperature of some 500° C. to allow the oxygen to pass off as carbon dioxide. leaving residual iron. At temperatures of 800° to 900° C., the iron becomes a pasty mass. At 1400° C.. cast iron becomes possible: but the latter, although produced occasionally at Meroë, was presumably considered a waste product, since use of cast iron —brittle and unmalleable—was beyond the technological abilities o
craftsmen of this period.

At the Meroë slag heap thr
which the railroad cut r
fragments of smelting-furnace
have been found. From these, we
an indication of the shape of Me
furnaces. My own research indi
that these ancient fragments cou
readily into the clay furnaces
today by the so-called Jur of
southern Sudan (photo, p. 18).

The Jur live along the north
of the river Jur in the Bahr el Gl
area. They were once famous for
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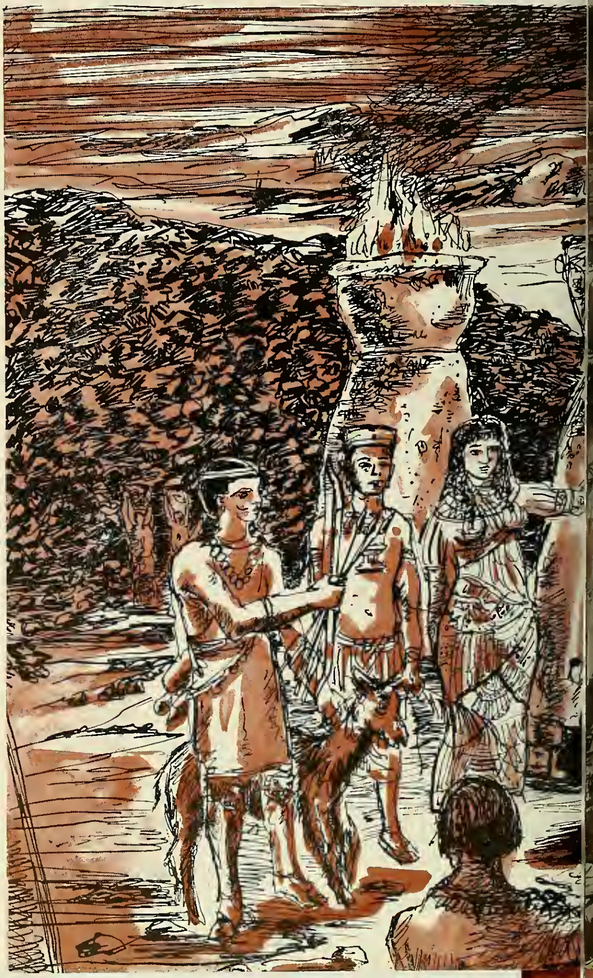
ceased. They do not use forced



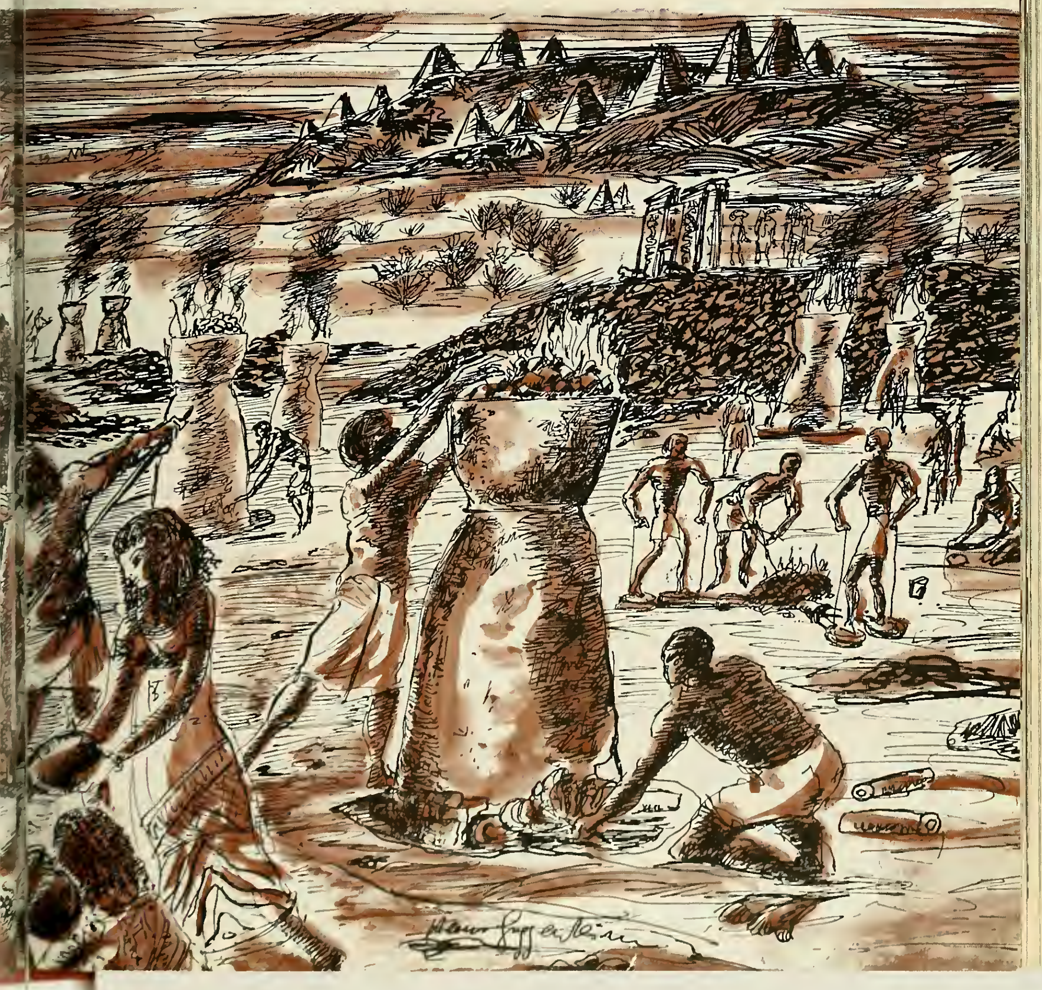
Reconstruction shows iron smelting at Meroë as priest, at left, presides at extraction of iron from a furnace. At right, men perform a second smelting.

a l they process the iron in two s ges. Their furnace is about six feet h h, with a diameter of two feet. It s nds inside a small, hollowed-out p Four to six openings are made s htly above the ground level. Into t se openings, short clay pipes (or t ères) are inserted, each about six i hes in diameter and two feet long. T se tuyères meet almost in the cente of the furnace and serve both as d ft flues and as fire bars. The furn e is filled first with some sixteen b kets of charcoal. On top of this are p ced three baskets of bog-iron ore t t has been broken into small p ces. One such charge takes nearly a ull day for smelting and produces e ugh bloom for eight to ten spearheads, or two to three hoe blades. The latter serve as bride-price money. An enormous amount of slag is produced in comparison to useful bloom.

Mr. Guggenheim, the author-artist, is indebted to Thabit Hassan Thabit, Republic of the Sudan Commissioner of Antiquities, for arranging trips to key sites, and to Dows Dunham, of the Boston Museum of Fine Arts, for his advice on Meroitic problems.

We can fairly imagine a similar design for the iron smelters of Meroë —an elongated "eggcup," into the top of which the ore is poured, while the main body, below, is stacked with charcoal. Dr. Dunham, one of the excavators of the Boston-Harvard expeditions to Meroë, has recently been kind enough to point out the resemblance of this eggcup shape to objects found by these excavators that were considered to be braziers. These miniature braziers are supplied with holes at the base that would facilitate a draft, and they show, further, that the eggcup form—like that of the smelter used by contemporary Jur ironworkers—was familiar to the Meroites.

Besides smelter-wall fragments, pieces of tuyères—the draft inlets—have also been found at Meroë, identical in size and shape to those used today by the Jur. These contain bits of iron slag at one end. It may be that forced draft, also, was used at Meroë. Bits of ostrich feather have been



LIGHTING THE FIRE for smelter is sacred act to Jur smiths, *top*. Although they have matches, smiths start this blaze in traditional way, with a wood stick.

TINDER CATCHES, *center*, and a smith blows on it for flame, *below*. The Jur still sacrifice a goat in the purification ceremony at place where ore is mined.

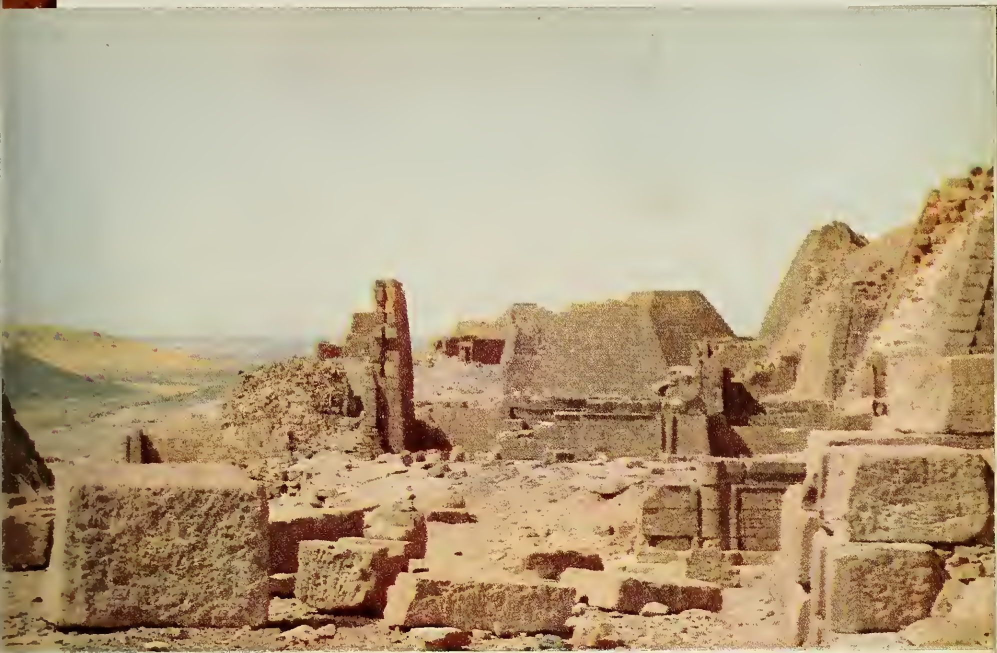
found that might be traces of used to force air into the furnace kilns large enough to accomm tuyères can operate on natural alone—as among the Jur.

THE Jur process gives us an how all this might have lo At the end of each firing, the fu wall is broken open and the iron that has formed at the bottom moved. The moment the lump i tracted, it is quenched with wate a torch is waved over it. This qu ing is considered very importa the Jur and is accompanied by p Strabo, in ancient times, consi the quenching most important f success of the operation; in fa classified the end-products on the of the water used.

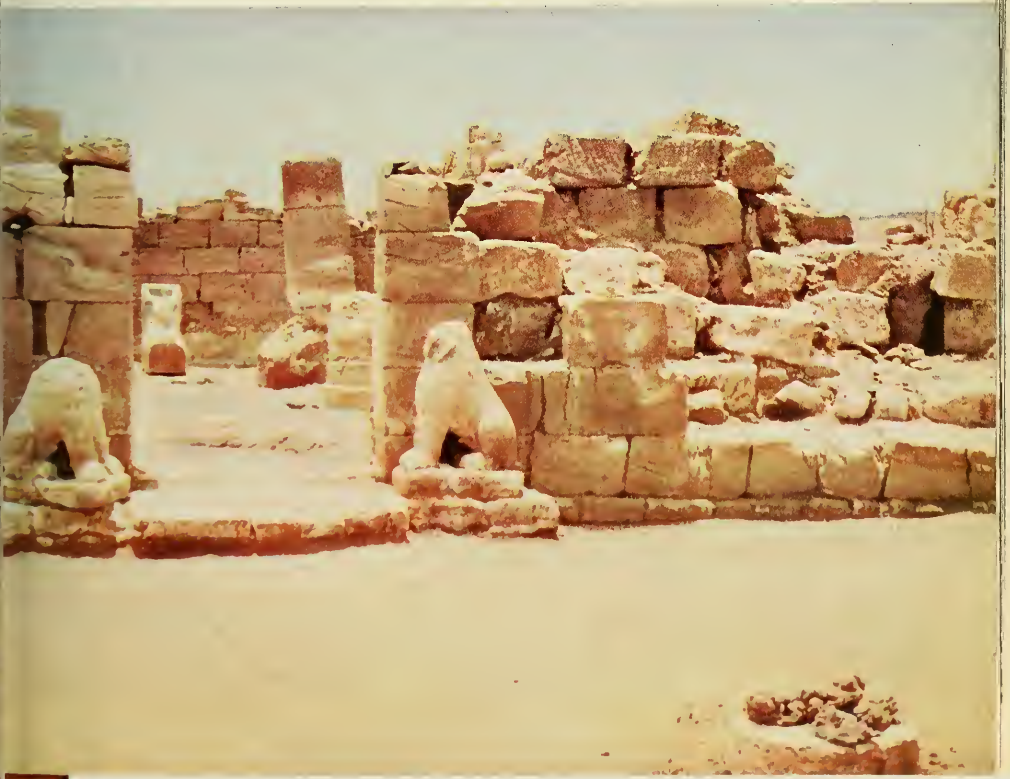
After the lump of mixed sla bloom iron has been quenched Jur break it up into small pieces. the second process can begin. great ceremony, the pieces of iro placed in a small clay crucible covered with charcoal. A chick slaughtered and waved over the Then. two pairs of bellows are u create a forced draft and brin bloom iron inside the crucible t heat. When the clay of the cr looks transparent in the red glo Jur know that the iron is ready worked upon by their smiths.

EGYPTIAN representations fro tomb of Rekhmire at T (fifteenth century B.C.) show may not necessarily be the first ing of iron ore (as has been gested) but a second stage—as the contemporary Jur method essary to refine the bloom iron first smelting. Meroitic furnace too, may have been broken afte smelting, in order to extract the

With this hypothetical d smelting in view. the presen small crucibles at Meroë—som of a mystery, since they could explained on the basis of the pr process alone—becomes more standable. Let us assume a smelting, after much of the sl been beaten out of the first-mel Charcoal, placed over a crucibl taining pieces of first-melt iron, add the amount of carbon to the necessary to make it workab achieve the temperature necessa this second smelting (1000 some kind of bellows for draft



P AMIDS AT MEROË, *above*, are tombs of Meroitic kings; ves seeking booty removed pyramid tops. *Below*, lions flank entrance to temple near Naqa. Object in foreground, topped by residue of ironworking, may have been an altar.

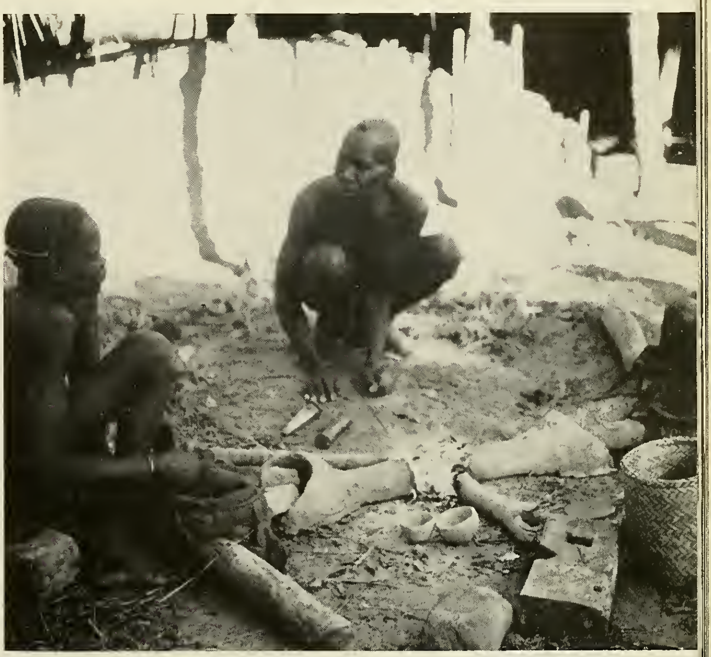


e been needed. The draft could
e been provided by workers alter-
ly treading inflated skins, as in the
resentation from Thebes or pump-
skin-covered drums, as the Jur do.
h methods are still common in
y parts of Negro Africa.

OMETIME between A.D. 300 and
340, Meroë came to an end. No
re iron was worked there, the city
abandoned and the Meroitic Em-
ceased. The reason remains un-
wn. In speculation that may not
entirely idle, one can imagine a
ge industrial proletariat, risen
nd Meroë's iron industry, that
w intractable. The pressure of
h a group, combined with the rising
of barbaric tribes such as the
bâ threatening the capital from all
es, may well have proved too much
an aristocracy softened by the
ury of Roman baths and elaborate
as. A situation not unlike that
ch existed in Rome itself a hun-
d years later may have prevailed.
any case, in 340 A.D., when the
umite king put up his victory stele
Axum—proclaiming his rule over
iopia—he did not even deign to
ntion Meroë.

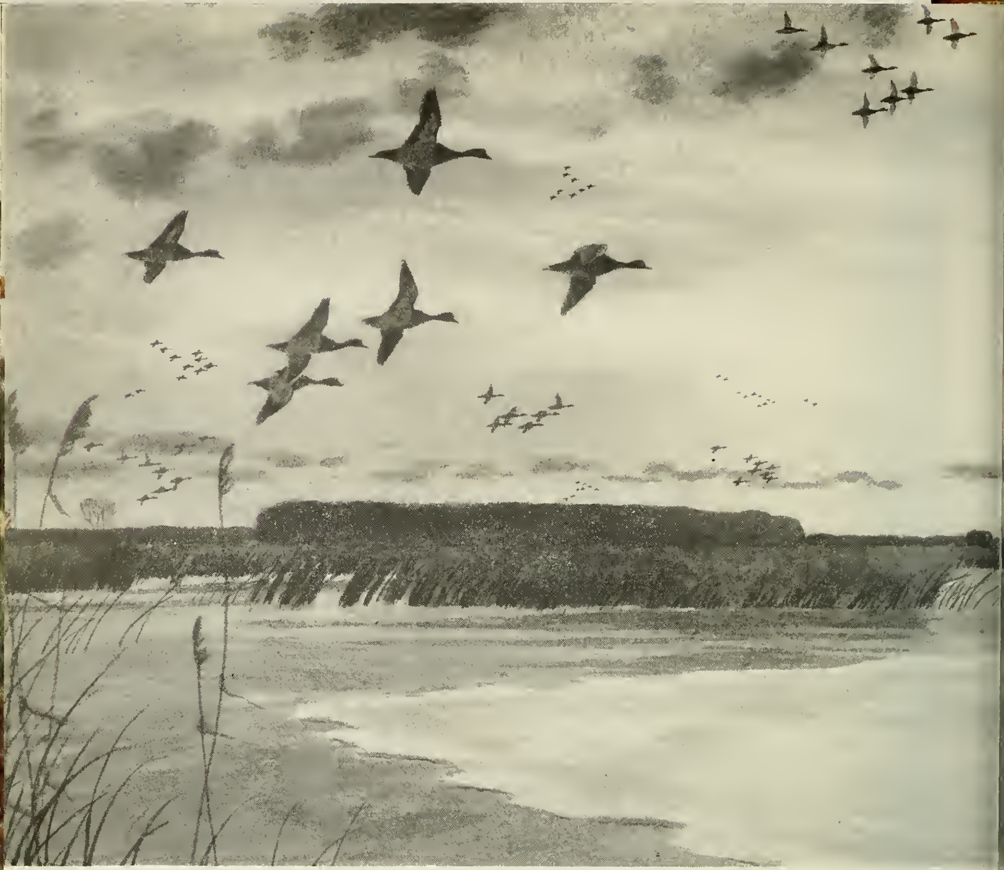
ot only are the origins of iron-
king at Meroë obscure, but that
ter's ultimate influence on other
ican civilizations is still a matter
speculation. It is possible that the
roitic knowledge of iron metal-
y diffused southward and east-
d together with other culture
ts, through Nilotic- and Bantu-
aking tribes. It is possible to think
t the great Bantu-speaking popula-
explosion of the eighteenth cen-
—which may have owed its
cess to the knowledge of iron—
still connected with the past glory
the Meroitic Empire. However, it
no means certain that the knowl-
e of iron entered Negro Africa
m Meroë alone. Carthaginian trad-
may have diffused this metallur-
al skill along the West Coast, while
ient Azanian traders touching
nalia, Kenya, and Tanganyika in
East may have provided still an-
er source. Only further research
l show whether ancient Meroë was
rime center for the diffusion into
gro Africa of that region's remark-
e, albeit primitive, Iron Age skills.

SMITH in a leaf hat, *left*, checks
lter draft. Tube at base is tuyère.



REMELTING IRON to purify it, Jur at left uses bellows of clay covered with goatskin for a forced draft. Two small crucibles near fire are to hold iron.

IRON HOE BLADES, attached to wooden shafts carried by Jur, may be used as money or for tilling fields. Soft metal soon wears out when used in latter role.



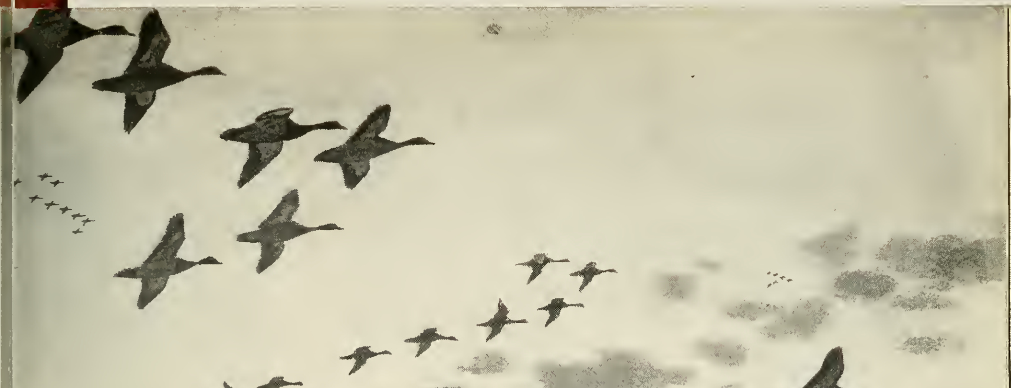
The Spring Passag

Breeding traditions draw migrant waterfowl to old nest si

By H. Albert Hochbaum

The early settlers of the prairie states began their agriculture in the heart of North America's finest waterfowl breeding range. The wetlands of Iowa, Minnesota, and the Dakotas were once as lush with sloughs and potholes as were the best of Canada, and probably just as attractive to marsh birds. Local waterfowl, however, made little impression on the residents, who left poor records of the numbers of ducks that nested in the early days. Resident populations always were overshadowed by the massive rush of spring migrants stopping for a while before flying on northward in their vernal passage. It was the same in the prairie provinces of Canada, where there are no records to compare the early numbers of breeding waterfowl with those of today. In Canada, too, it was the spring passage that was most in
sive, and the pairs that remain
nest seemed insignificantly few.

The general failure to realiz
importance of local breeding p
tions is because the ducks space
selves rather thinly over their n
range. Gregarious through m
the year, they separate pair by
once they have arrived on
grounds. In most species an i



e for other breeding pairs of the ne kind develops. Thus mallards ght sit side by side, pair by pair, in herings of thousands on the Illi- s River in March, but in April a rth Dakota or a Manitoba slough ommodates only one pair of mal- ls at a time. Migrants keep going ther north because, for one reason least, there is not room to serve re pairs locally.

hile one mallard pair will not erate other breeding mallards, it l live peacefully with a pair of pin- s or gadwall, which, however, will permit the close presence of ers of their own species. Some ds, however, have smaller spatial uirements—hence a pothole hold- only one pair of mallards and one r of pintails also will serve as the idence of two or three pairs of e-winged teal. And the spacing of heads and some other diving ducks is not as well defined as in the mallards. But for all kinds, this territorialism means that breeding pairs do not congregate in flocks.

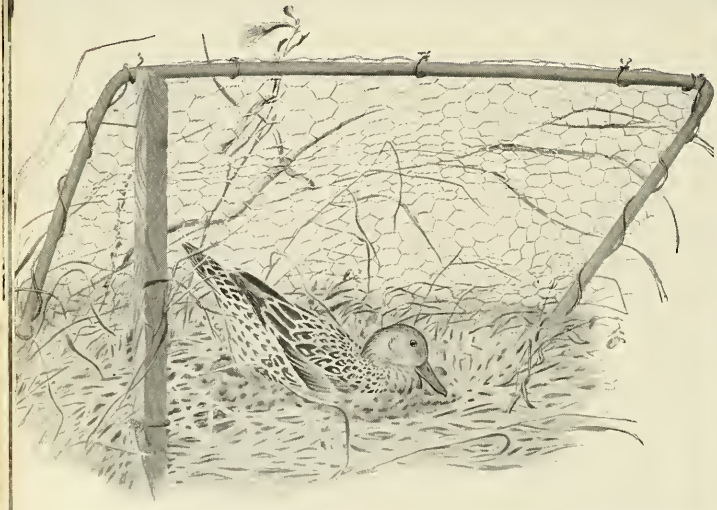
INSTEAD they spread themselves widely over the landscape. Moreover, since loafing spots are an essential component of waterfowl territory, large bodies of water that attract great numbers of migrants are virtually empty of those breeders that are confined to the shore lines. Slough and pothole country, with its many separate waters and abundant loafing situations, provides the best pattern of territorial terrain. It is on such range, often in the heart of agriculture, that the heaviest breeding densities of ducks are found. Indeed, the intensely farmed country round Waubay, South Dakota, held 124 pairs of breeding ducks per square mile in 1951, while the best counts on the delta of the Mackenzie River, one of the finest northern breeding grounds, showed only 26 ducks per square mile nesting there that year.

With the growing interest in local waterfowl, many naturalists in the more or less settled parts of the United States and Canada will visit numerous small marshes and quiet shore lines this year in the hope of locating breeding pairs of ducks that remained on after the main flight continued north. An isolated pair seen day after day on the same pond or loafing bar is a good indication of nesting interest. If subsequent observations find the drake by himself in the mornings, chances are good that his hen is busy at her nest. Another reliable clue to breeding, most conspicuous in mallard, black duck, and pintail, is the *"three-bird chase."* When a pair intrudes upon the breeding territory of another, the resident drake rises in attack. There results a dashing, spirited pursuit in which the attacking male drives at the intruding female, pressing hard at her very tail. All the while her own mate lags behind or to one side. The flight is seldom of great duration; after several hundred yards, the attacker sets his wings to scale back to his pond, returning to the side of his mate, who rarely joins in the conflict. It is not yet understood why the male pursues the intruding hen rather than her mate, as is the case in most territorial disputes. But this three-bird chase, seen most often in twilight, is evidence of the presence of local breeders.

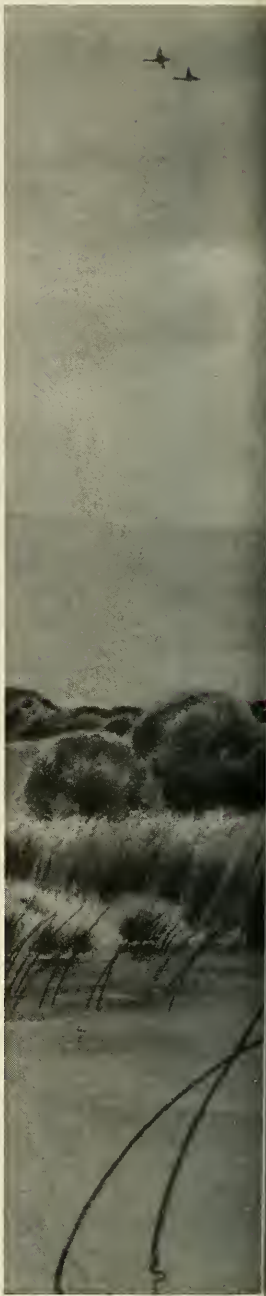
THE male remains on his territory until his mate has completed her clutch. Then—in mallard and pintail, canvasback, redhead, and most other species—he rapidly loses interest, soon departing to join bachelor friends foregathering in advance of the eclipse molt. In some species, however, notably the blue-winged teal and the lesser scaup, drakes may remain faithful long after the hen has started to incubate. Day after day the male waits at his post, his bright plumage gradually being replaced by the drab eclipse until he is but a shabby shadow of his former self. Despite such loyalty, the drake seldom attends the hen once she has appeared with her brood of ducklings.

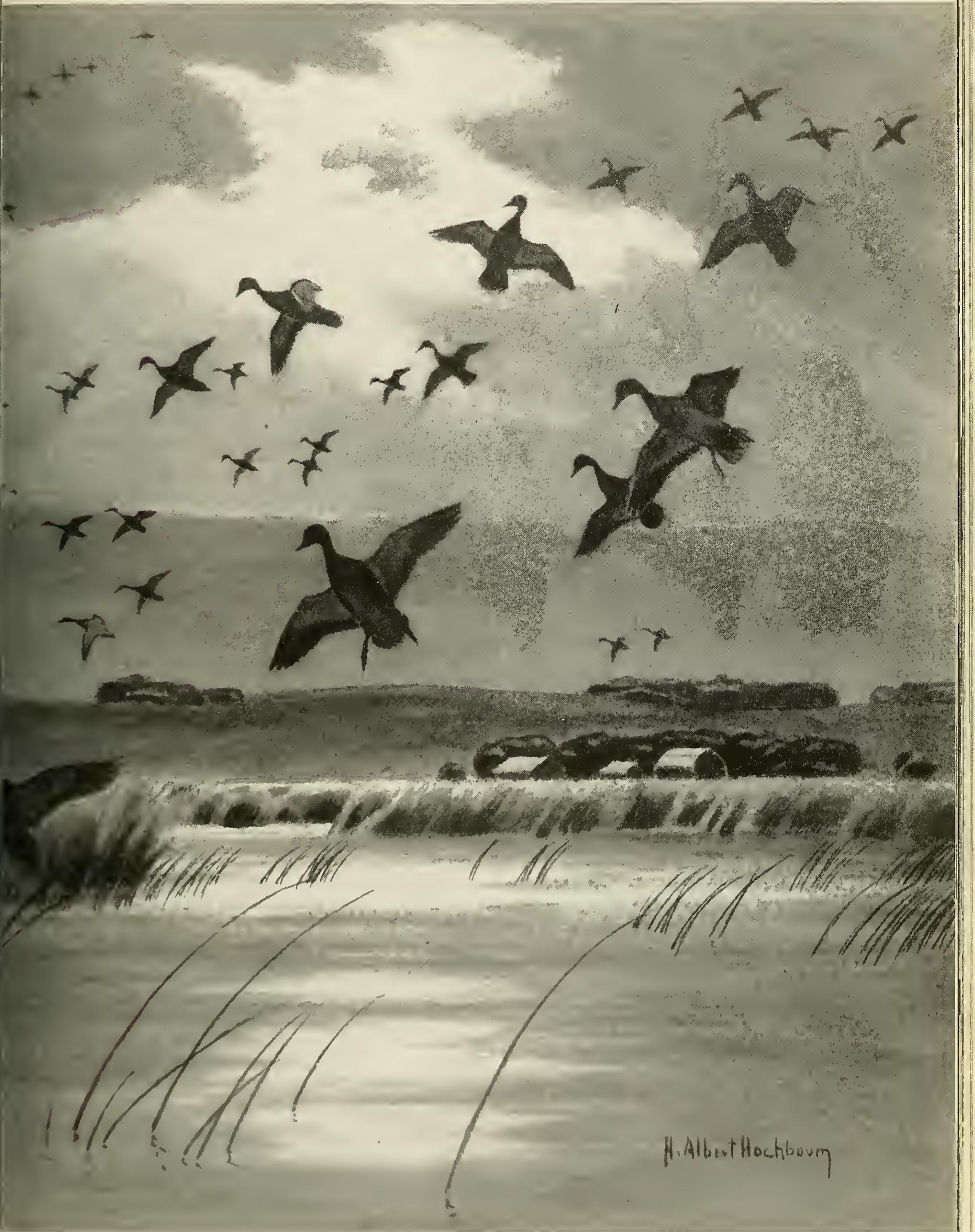
In the bigger birds the space requirements are much greater. Both whistling and trumpeter swans establish defended territories, which may be over a mile in diameter. The Canada goose shows variable behavior: some individuals defend huge territories, while others may nest in rather close association. The snow geese and blue geese breed in colonies with nests and territories crowded closely together.

Studies with marked individuals show that the female duck comes back in spring to the same place she used the year before. Dr. Lyle K. Sowls followed the homing of ducks at Delta, Manitoba, by color-marking and banding hens at their nests. Each spring nearly every female on a large study area was captured at her nest by means of a simple drop trap. New birds were color-marked and banded, while the return of old individuals was documented by the identification numbers on their leg bands. Sowls captured one shoveler nesting in the same meadow each year for four consecutive seasons, and the annual recovery of many others led him to conclude that female ducks return to their original nesting place each spring for as long as they survive and the area remains suitable. The drake, of course, cannot be so faithful. Pairing takes place on the wintering



PULL ON STRING, *left*, drops trap on incubating pintail, who will be banded and code-colored or, if already banded, checked for fidelity of return to site.





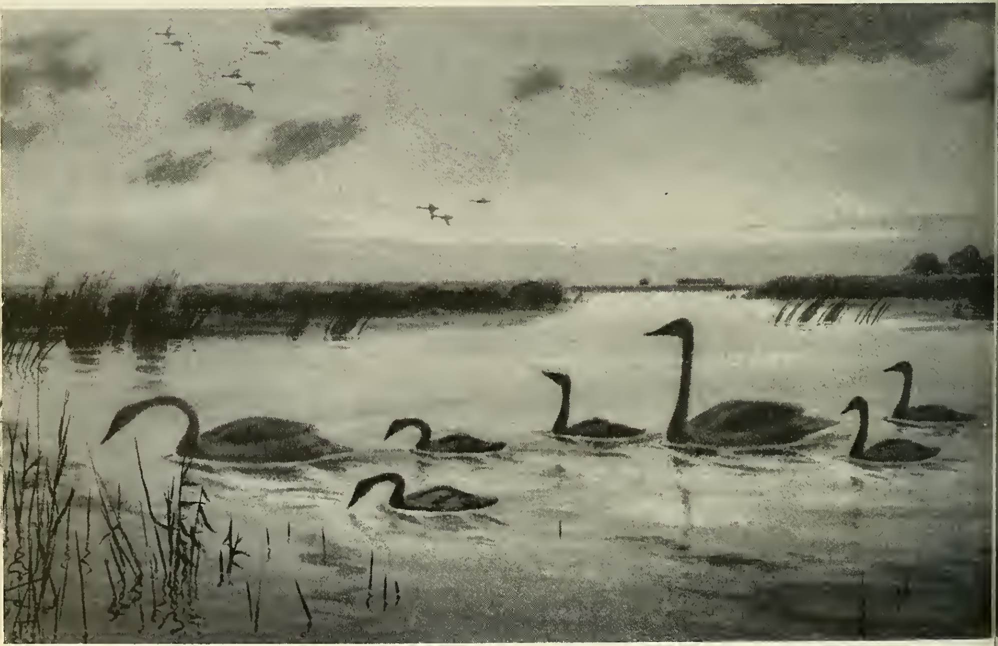
I THE PRAIRIE STATES, some young *mallards* and *pintails* on the wing in early June, exploring the region where they were born and learning the details of the home country to which many of them will return to breed the next spring.

grounds in many species, and new matings occur each spring. Thus, a Manitoba male might mate with a Saskatchewan hen and must follow her to her own home range.

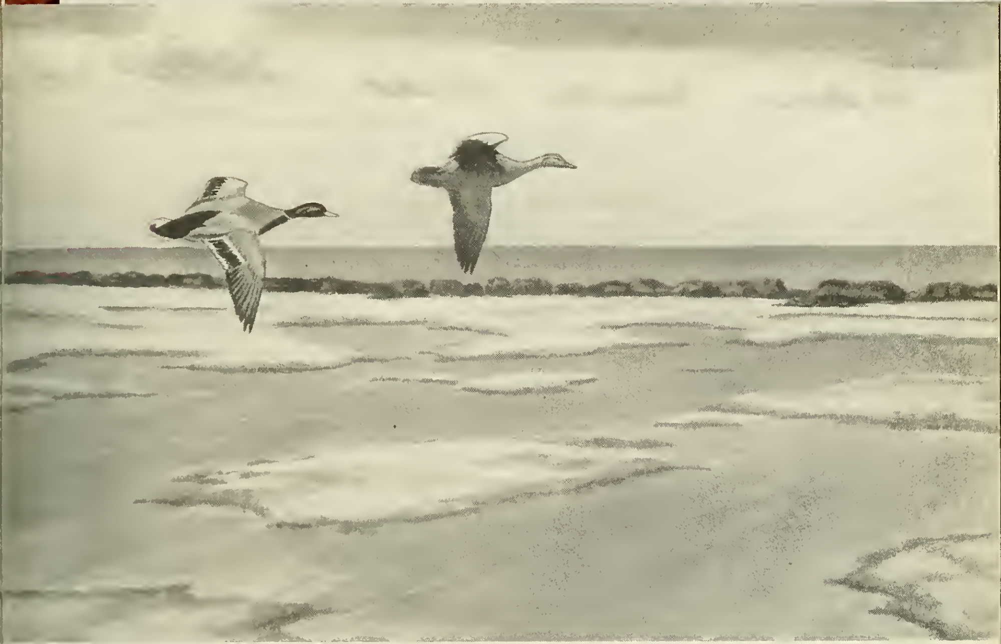
Sowls discovered that the first ducks to return in the spring migration were the adults. This, he noted, gives the old birds an advantage in competing for space. Banding studies indicate that young females find their way back to their natal ranges their first spring, but seldom nest in the same patch of cover where they were hatched. Yearlings return to the place of familiarity learned the previous summer, and yet, with stiff competition for territories, they may be obliged to settle down some distance from the exact site of their birth. Pioneering to new nesting areas is probably accomplished by such young birds that are setting up their first nesting localities.

Young ducks never see their father, and their mother leaves them forever when they are ready to fly. The young of the Canada goose, on the other hand, remain with the parents after they are fledged. Young geese, therefore, have little opportunity to explore their surroundings their first summer. They travel south with their parents as a family group and return with the old birds the first spring. Thus, as family traditions are stronger in the geese, breeding populations are more restricted in area. Young Canadas do not breed during their first or second springs, but when the females start nesting in their third year, they settle down near the place where they were born.

The homing of waterfowl to native ranges means that many attractive marshes are passed by as the migrants press on to reach familiar grounds. So it is that when local breeding populations in the United States have been decimated to the point where there are not enough birds to use all existing habitats in spring, the vacant space is not occupied by passage migrants. Spring travelers stop for a while, but eventually move on beyond such untenanted marshes, no matter how attractive. This is most noticeable in species such as the Canada goose
trumpeter swan, which have s
breeding traditions. Once the Ca
goose was a common breeder i
middle western United States.
remain fine goose marshes
today; but the local breeders ha
been killed; there are no native
remaining with breeding exper
in this region. All the migrant
common in the Middle West d
autumn and winter, have far
destinations when spring arrives
trumpeter swan has been comp
extirpated from Minnesota and
other central states, which were
home. The geese and the swans
not driven out by settlement,
many believe. Neither requires a
tine situation, and there are
peter swans now nesting within
of farmsteads in the Peace River
ley of Alberta. All geese and s
with local experience were kill
the spring and fall wild-fowli
the early days, and the two sp
vanished as breeders. The same
is happening with the canvasbac
redhead ducks. Despite the dra



Trumpeter swans still nest in marshes of some farm areas in Alberta. At one time, bird bred in Minnesota, Iowa, and other midwestern states. However, those swans accus
to nest in such areas were killed as the country was s



IR OF MALLARDS, on way to Delta Marsh, first sight Lake nitoba, then locate home range in their familiar marsh nesting pattern. Migrant ducks fly over open expanse of the lake, and passerine birds follow wooded ridge at its edge.

many breeding marshes in Minne-
a and the Dakotas, there still re-
in some good areas with ideal
ting situations for the two species.
pulation counts of resident pairs
w, however, that there has been a
iceable and steady decline of native
vasback and redheads.

A reverse process may re-estab-
lish waterfowl to burned-out
eding ranges by the simple pro-
s of introducing young stock. When
htless juveniles are released in a
w area, it becomes their home,
l after their first migration south-
rd they return there rather than to
ir birthplace. Most successful of
such plantings have been with the
nada goose. Now there are many
eding groups to delight local cit-
nry with their music and the aerial
tern of their wings. Some building
breeding populations has been ac-
nplished on state and Federal wa-
fowl refuges, but many bands are
w located in parks or lakes of cities
h as Rochester, Minnesota, or Den-
r, Colorado. The trumpeter swan
ght be similarly re-established as a
eding bird on suitable situations
ll remaining within its former
meland in Minnesota and perhaps
in other states where it once nested.

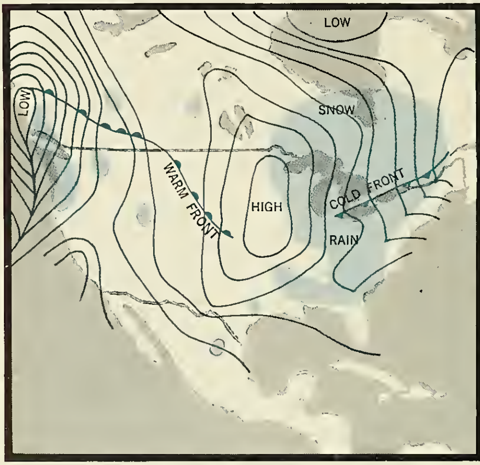
The vernal homing of waterfowl and other spring migrants has puzzled man throughout his history. The manner of orientation still is not clear, but various studies including the many successful transplantings of the Canada goose in the United States make one point clear: a duck is not "instinctively" related to the place of its ancestral home. That is to say, there is no genetic tie linking a duck or a goose to its home range. Each individual learns its surroundings and returns to nest at this familiar place. If, as a flightless young bird, it is removed to a location far from its birthplace, this new area becomes its home grounds—the familiar range that it explores in its first flights—from which it migrates in autumn and to which it returns its first spring. Young waterfowl must learn the details of their homes, and the return in spring migration is the result of learned experience.

The immensity of the feat of homing is perhaps overemphasized when, as with an individual hen, we stress the fact that she "pinpointed" back to the exact nesting place used the previous year. After all, to find this precise spot, the hen first located the larger nest site within which she had had some rather wide experience. Moreover, we know from banding studies that females often range beyond the home marsh after the young are reared, thus further broadening the area of familiarity. A homing hen need not aim her long journey toward the exact nest site. She may strike a much wider objective, and once there she travels over familiar ground to her special nesting spot. The breadth of the "target area" in spring migration is further increased by the advantage of the aerial view gained in migration. At 2,000 feet elevation, for instance, the horizon is about 60 miles to either side. A female arriving at this height sees an area of landscape nearly 120 miles across. The distance of recognition may be further increased by outstanding landmarks. When returning to the Delta Marsh, an arriving hen first sees Lake Manitoba, which is 30 miles wide. A mallard with a home range on the west shore might sight the lake 90 miles east of her nesting place. Once Lake Manitoba was in view, the home marsh would be an easy mark.

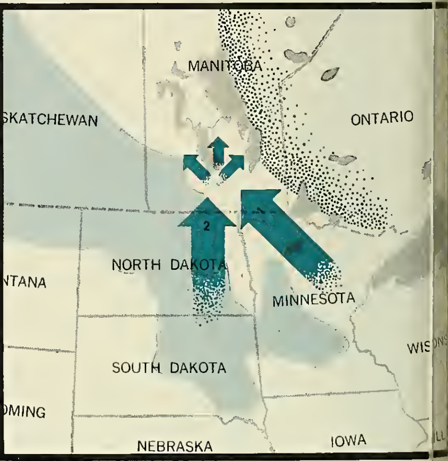
Let us remember, however, that landmarks are not the only guides to migrational orientation. By the work of modern students of bird behavior —notably Dr. G. V. T. Matthews of England and Dr. Gustav Kramer of Germany—we have gained evidence that the sun and perhaps other heavenly bodies help guide birds in their spring journeys homeward. Such solar guidance is not simply in terms of compass direction by which, for instance, the sun serves as a directional cue to man in local travels. The arc of the sun, together with the schedule of its passage across the sky (man and birds perceiving the sun, as Joshua did, in movement relative to the earth), provides reference to the position of a traveler in terms of latitude and longitude. As the bird flies north in spring, the sun's arc becomes progressively lower, the angle of its ascent and descent more acute. If travel is also across degrees of longitude, as when a flock of canvasback goes northwest from Chesapeake Bay to Minnesota, the sun rises later and sets later as each step of the journey is accomplished. Birds, of course, have no clocks, but their awareness of time—probably from metabolic cues—is extremely sensitive.

The ability to orient to the sun implies that spring migrants need not be familiar with every detail of landscape on the long way home. An awareness of their situation relative to the sun establishes the correct general direction of travel even when the landscape is not familiar. Individuals are not obliged to follow exactly the same routes each season, step by step, and at Delta, Manitoba, annual variations in the volume of spring travelers suggest that sometimes the bulk of the passage bypasses the south end of Lake Manitoba. Nor must we ever forget, as we marvel at the precision of avian orientation that each year countless numbers of birds become lost, some to delight the ornithologist with the sight of a rare stranger, strayed far from its native habitat.

The homeward migration of waterfowl begins as soon as winter weather relinquishes its hold and open water appears in the central United States. In the mass movements of autumn freeze-up, ducks often fly great distances, continuing on through the night and into the next day before making their first stop, which may be at least a thousand miles from the starting place. In spring, however, the passage is generally in shorter steps as the vanguard keeps pace with the slow advance of the thaw. The movement is in definite waves, which are clearly related to the regular flow of high- and low-pressure areas. Little or no migration takes place during high-pressure weather with its sunny skies and cool north winds. During the cloudless nights of a "high" in early spring, the open waters may



Weather map of April 8, 1954—day following Manitoba's worst blizzard of year—shows a day that brought migrants to northern Great Plains, but delayed migration in the East.



Spring migration in upper Great Plains is usually ron south or southeast. From Delta, birds splay out nort ar Nesting is now heaviest in south of pothole area (sh ed)

MILY OF CANADA GEESE flies high on its vernal migration meward. The young of these geese, unlike those of ducks, fly southward in company with their parents in the autumn, returning with them to the home marsh the following spring.

eze tightly, inducing a southern re-
at of the earliest arrivals. Some-
es a high remains stationary,
ving days of clear sky and fine (but
ld) weather, which to the human
server seems ideal for spring pas-
ge. But the migrants wait out such
ells. Indeed, when such a stagnant
h holds reign it would be pointless
waterfowl to move, as the lakes
d marshes remain solidly frozen
ly a short distance north.

VERNAL travel begins after the high-
pressure air mass has moved
ng in its own migration, which,
central North America, is in a
utheasterly direction. As the anti-
clone shifts on its way, a clockwise
rculation of air brings southeast
nds along the westward portion of
e high-pressure area, and with this
e birds take off on another step of
their homeward journey. When a strong high is followed immediately by a low-pressure area, the change of weather and the arrival of migrants is unbelievably swift. For instance, on April 7, 1954, weather in southern Manitoba was dominated by a high centered in northern Saskatchewan. Winds of 20–25 mph from the northwest created the worst blizzard of the year. The snow blew like dust, reducing visibility to 20 to 30 feet, even though the sky was clear and the sun shone brightly all day. The wind dropped by nightfall. Next morning warm southeast winds of 15–20 mph brought an avalanche of migrants of many species, the heaviest passage of that entire spring.

The very nature of the weather often contributes to the shortness of spring travel, even late in April when the thaw is well advanced. The south winds favoring the travelers are warm and moist. When it overrides cold air to the north, rain, snow, or fog results. Birds starting out under ideal conditions may quickly run into a storm bad enough to halt their northward movement. Sometimes the passage barely gets underway before it must stop. Waterfowl at Delta, Manitoba, sometimes leave the marsh in balmy weather that creates fog when the soft winds strike the frozen lake. The birds turn back almost as soon as they have started. Contrary to a common misunderstanding, birds cannot maintain migrational orientation in a fog, and when dense mist settles over the area, travel is halted.

At the onset of spring migration, wildfowl in large numbers move in a standard direction toward their breeding grounds in the distant north. At each step, however, once the northern states have been reached, some birds break from the common route and go their own special way. Canvasback, for instance, may have traveled together from Chesapeake Bay to Lake Christina, Minnesota. But from there they are destined to go to different home marshes, some to the sloughs around Mahnomen, Minnesota, some to the Lake Winnipeg marshes, others breaking farther to the northwest for the Delta Marsh or the Minnedosa pothole country. With the breeding range of ducks spread so widely over the prairies and the northland beyond, the pattern of homeward migration must eventually show as many divisions as there are pairs in flight.

It is probably because of the vast numbers of individual destinations that units of migrant flocks of ducks are small by the time they have arrived on the prairie provinces of Canada. At Delta, Manitoba, departing bands seldom number more than a dozen birds together. Their heaviest flight is into the northwest toward the same point of the compass whence the main flights arrived in autumn. Smaller numbers go north or northeast. The main passage of Canada geese is to the north and northeast. Rarely do these birds fly northwest with the main passage of ducks, although it is the direction followed by whistling swans. The massive movement of blue and lesser snow geese is northeast along a line of flight leading to their next rendezvous on James Bay. Probably most birds make decisions on flight direction at the start of a journey, but on April 20, 1952, Mr. J. W. Baldock of Winnipeg saw a flock of Canada geese split in their flight north along the Red River Valley, one group branching off toward Lake Manitoba, the remainder continuing on toward Lake Winnipeg.

On the Canadian prairies the beginning of each migrant journey of ducks is in the late afternoon or early evening. Passage continues through the twilight and sometimes into the dark of night. The short steps of migration may be completed while there is some twilight remaining in the sky, for the sun is past the equinox, and the angle of its descent gives a long afterglow. A duck departing at sundown might travel 150 miles or so before the last light fades from the sky.

Illustrations for his own text were executed by MR. HOCHBAUM, who is the Director of the Delta Waterfowl Research Station in Manitoba. His prime interest is waterfowl ecology.

During the early spring at Delta, Manitoba, most arrivals are seen in the evening dusk. They are probably birds that started their travel only a short distance to the south. Later in April, however, new birds may be seen coming in during the morning, no doubt having started from distant points the night before. Most mallards, pintails, and other river ducks are paired when they reach their Canadian breeding grounds, and the migrant flocks are distinctly made up of couples. Some canvasback, redhead, and other diving ducks likewise arrive mated, but mostly the composition of their flocks shows an unbalanced sex ratio, with drakes outnumbering hens and none of the females firmly attached to a male.

What happens when ducks return after a winter in the southland to find the home country untenable? What if fire or agriculture has destroyed all the nesting cover or, worse yet, if the water has vanished with drought? Wildlife managers have long assumed that when a breeding area becomes dry, the ducks native to that place simply shift to a more favorable location, there to set up housekeeping at once. Indeed, the state and Federal waterfowl breeding refuges in the north central states were established with such an emergency in view; surely these marshes would serve the greatest function as breeding areas for birds displaced during dry years.

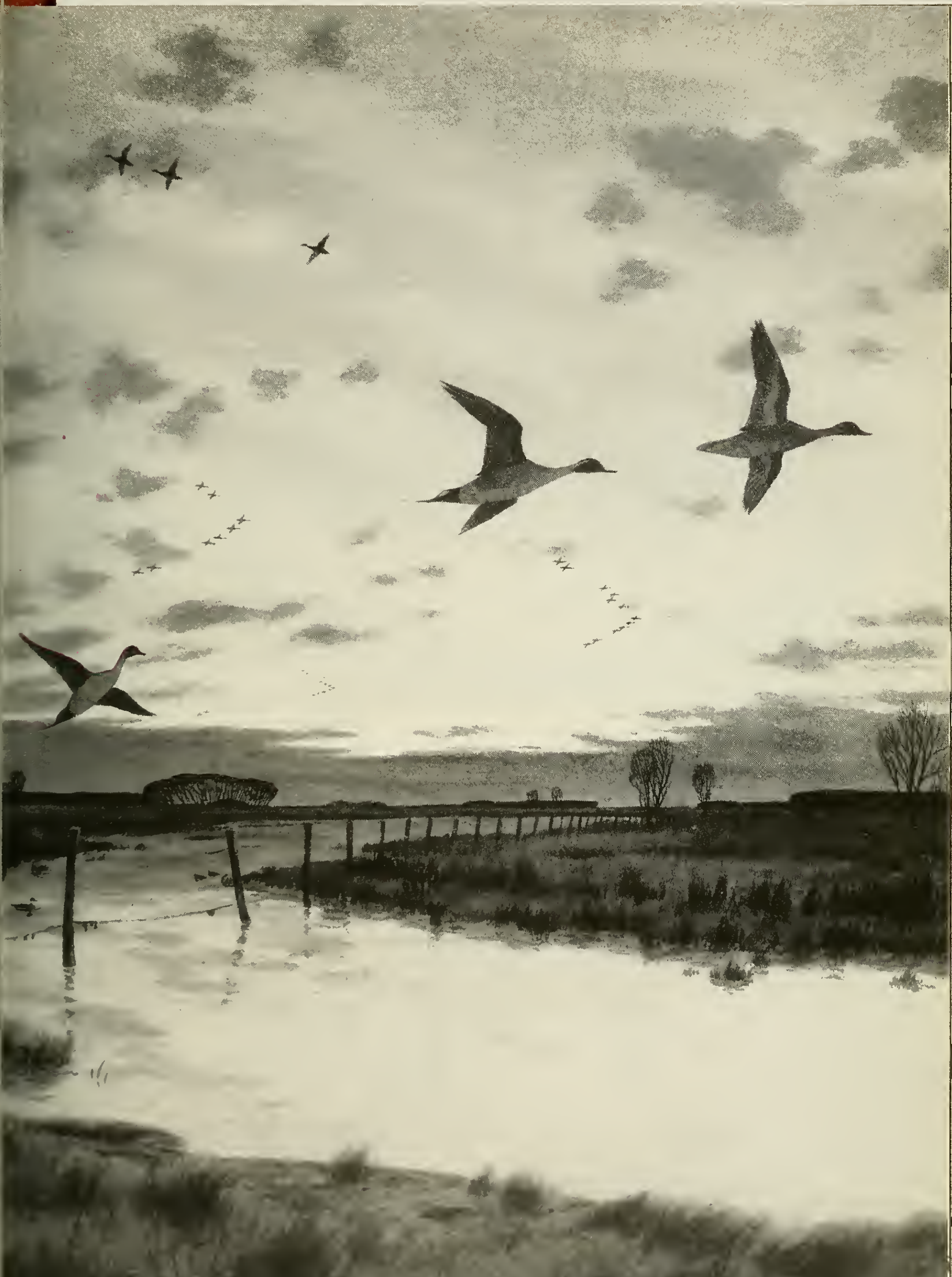
The drought of the late 1950's in North Dakota and the prairie provinces was the first massive dryout since intense biological interest in waterfowl habitat was awakened. Refuge managers in North Dakota and Minnesota and biologists on the larger marshes in Manitoba were heartened in June, 1959, by the arrival of many flocks of paired ducks, evidence of a massive late shift. Drakes and hens were together in pairs, still immaculate in bright breeding dress, apparently eager to settle down to nest on new locations. Settle down they did, but before June was finished it was clear that most had lost all urge for nesting that year. They simply sat about in groups of pairs, passing the time of day without attempting to establish a reproductive schedule. Some, perhaps, h
started to nest on their home groun
but, thwarted by lowering water l
els, had departed. Others nested
lost their eggs to predators that we
more than usually efficient in the po
cover—for when the sloughs began
dry, farmers either burned much
the surrounding vegetation or plow
it under. After losing their first ne
the birds attempted no renestings
pond margins continued to rece
Many others may have given up wi
out trying. Once these birds ha
gathered in flocks again and moved
a new range, they have abandoned
productive efforts for the year.

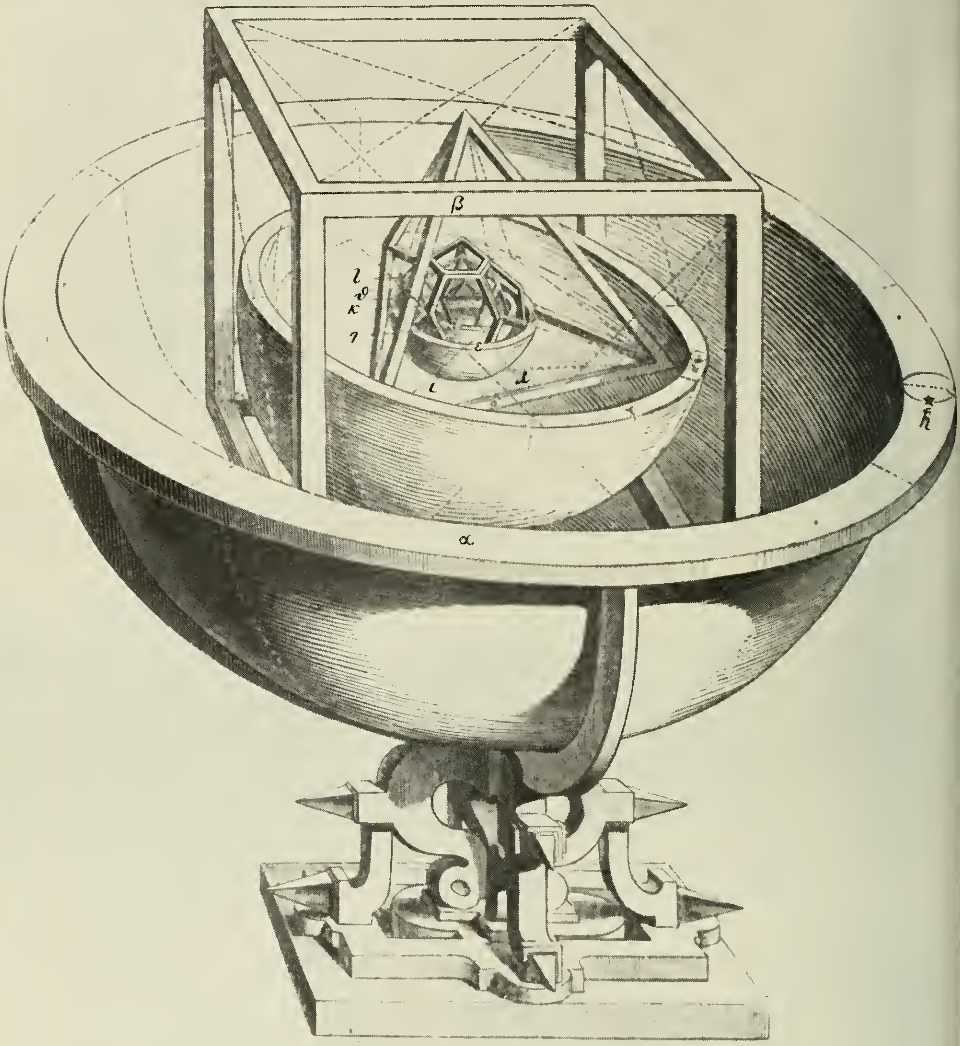
In normal years of good wat
migration barely ends in a
given region before some waterf
are on the move again. With the m
passage having departed from nor
ern Minnesota and southern Ma
toba by the first week in May, sm
groups of early breeding mallard a
pintail drakes already are break
away from their hens and territor
First they are seen together in tw
and threes, then in bands of a do
or more by mid-May. By late M
these flocks of bachelors are drift
away from the scattered breed
areas to the larger marshes in a m
migration that carries some indi
uals long distances from where th
mates nested. By the middle of J
some of these drakes are in
eclipse plumage and are flight
with the molt of the wing feathers.

In the prairie states some you
mallards and pintails are on the w
by the end of June, exploring th
natal range, learning the home co
try to which they will return to br
during the following spring—that is
which they will return if their ma
lands are still there another spr
Each year sees fewer marshes in
prairie states and provinces,
many of the breeding places
drained under government subsid

This is largely a case of lack of
formation. Both administrators
the general citizenry believe
drainage and ultimate loss of slou
and potholes is of minor importa
because waterfowl will, time with
end, breed somewhere beyond the
izon. Sadly—tragically—this is not

IN THREE-BIRD CHASE, an interlop
female is repulsed by a resident m
while her mate, left, lags far beh





α Sphaera Saturni. β Cubus. γ Sphaera Jovis. δ Tetraëdron. ε Sphaera Martis. ζ D decaëdron. η Orbis Terrae. ϑ Ikosaëdron. ι Sphaera Veneris. ϰ Octaëdron. λ Sphae Mercurii· μ Sol, Medium sive centrum immobile. (Comp. Fol. 214.)

SKY REPORTER

Johannes Kepler and the start of modern celestial mechanics

By Simone Daro Gossner

TYCHO BRAHE's observations had attained a degree of accuracy never achieved by any of his predecessors. His foremost ambition had been to use these collected observations to prove the validity of the planetary theory he had proposed. Unable to complete this task in his lifetime, he had entrusted it to his assistant, Johannes Kepler, with the expressed hope that the latter might indeed vindicate the Tychonic system. Ironically, Brahe's observations were destined to provide the foundation for Kepler's own momentous theories of planetary motions, and the Tychonic system was buried with its originator.

Kepler was born at Weil der Stadt, in Swabia (Germany), on December 27, 1571. His strict Lutheran upbringing played an important role in his career. During this period, the Catholic and Reformed churches were vying for control of the various German and Austrian communities; more than once, Kepler was forced to abandon both job and home, and to set forth in search of another position and a new patron.

His college years were spent at the University of Tübingen as a student of theology. Even then his unusual aptitudes for mathematics and astronomy were encouraged by one of his teachers, the astronomer Maestlin. Although the teaching of Copernican theories was opposed by the church, Maestlin discussed them in private sessions with his pupils. Quick to perceive the advantages of the new system over the traditional Ptolemaic view, the young Kepler sought to assemble all arguments in its favor.

In March 1594, Kepler interrupted his theological studies to accept a post as mathematics teacher at the seminary of Graz (Austria). From then on, his career was to be devoted to the physical sciences, but his methods and his search for scientific truth continued to reflect the deep mysticism of a very religious man.

The Copernican system provided the means of determining the relative distances of the planets from the sun. Kepler, convinced that the divine arrangement of the solar system did not leave those distances to chance, first sought a general law by which they could be explained. His original theory was outlined in an early work, published in 1597 and usually referred to as *Prodromus* (Precursor) or *Mysterium cosmographicum* (Mystery of the Universe)—both being abbreviations of its unwieldy title. Naïve though the system may seem now, Kepler thought of it at first as the revelation of a fundamental truth. It supposes that the orbit of each planet lies on a sphere, and purports to show that these spheres can be alternately inscribed and circumscribed to the five regular solids mentioned in Euclid's geometry (illustration, *left*).

EUCLID'S FIVE SOLIDS were at first thought by Kepler to provide a clue to the divine arrangement of the planets in our solar system. Each planet's supposed spherical orbit is shown, *left*, to lie inside one or another regular shape.

Kepler was the first to recognize that his model of the solar system did not agree fully with observations. Those observations to which he had access were of poor quality, however, and the only reliable ones extant—Tycho Brahe's—were jealously guarded by the latter. By a sudden change of fortune, Kepler was banished from Graz shortly thereafter and invited to seek refuge at Brahe's observatory near Prague. At Brahe's death, a year later (1601), Kepler was appointed as his successor, and thereby came into possession of his monumental records of observations.

Kepler chose as one of his first tasks the analysis of the motion of Mars. Mathematical methods in use at that time were extremely crude. The calculus had not yet been invented, but Kepler's ingenuity supplied the stratagems necessary to solve the problem at hand. Whereas Copernicus still placed the centers of planetary orbits at some distance from the sun, metaphysical convictions led Kepler to assume that the sun must be the true center of motion and perhaps the source of the motive force that keeps the planets moving (the first hint of what Newton would eventually call gravitation). Since the distance of a planet from the sun was known to vary along its orbit, Kepler rejected any a priori concept of circular motions, in spite of those he had assumed in the *Prodromus*.

Noting that Mars moves more slowly when its solar distance (or radius vector) is greater, he showed by laborious calculations that faster speeds are compensated by shorter distances and, conversely, slower speeds are compensated by longer distances, with the result that *the radius vector sweeps equal areas in equal times.*

AFTER trying to fit various oval shapes to the orbit, which, obviously, could no longer be considered circular, he reached the remarkable conclusion that *planetary orbits are ellipses with the sun at one focus.* These two laws of motion first appeared in his *Astronomia Nova* (1609) after four years of delays and financial difficulties.

Kepler's third law, the crowning achievement of his new cosmology, lies hidden in the last part of an extraordinary volume entitled *Harmonice Mundi Libri V* (The Five Books of World Harmony) published in 1619. Comparing the periods of the planets—that is, the times in which they complete one revolution around the sun—with their mean distances from the sun, he had found that *the square of the period increases as the cube of the mean distance.*

With the formulation of his third law, Kepler had come almost full circle since the *Prodromus*. Once again, it was his profound mysticism that had led him to seek a mathematical expression that could represent an orderly universe but, in this latter venture, his acquired knowledge of precise planetary motions had served him in good stead. Kepler's third law, as in fact the other two, were to require only slight modifications at the hands of Newton and his successors. After many weary centuries, thanks to Kepler's efforts, the modern era of celestial mechanics had begun.

THE SKY IN MAY

From the Almanac:

Last Quarter	May 7, 10:58 A.M., EST
New Moon	May 14, 11:55 A.M., EST
First Quarter	May 22, 11:19 A.M., EST
Full Moon	May 29, 11:38 P.M., EST

For the visual observer:

Mercury, in superior conjunction on May 1, will be too close to the sun to be observed in early May. In the evening sky throughout the month, it will be visible near the western horizon after dark during the last half of May. The planet will set an hour and a half after the sun on May 15, and two hours afterward on May 31. It will reach its greatest eastern elongation on May 31.

Venus, in the constellation of Pisces, will rise at about 3:30 A.M., local time, on May 1, at 3:00 A.M. on May 15, and at 2:30 A.M. on May 31. It will attain its greatest brilliancy (—4.2 magnitude) on May 16 and will be very conspicuous in the eastern sky before sunrise.

Mars, in Cancer, will be up in the western sky at dusk and will set in the northwest at 12:30 A.M. on May 1, and at 11:45 P.M. on May 31. Its brightness will fade gradually from +1.3 magnitude on May 1 to +1.6 on May 31.

Jupiter, in Capricornus (—2.0 magnitude), will rise in the southeast at 1:00 A.M. on May 1, at midnight on May 15, and at 11:00 P.M. on May 31. It will be found in the southern sky at the time of sunrise. The planet will be at a stationary point in its apparent orbit on May 25.

Saturn, also in Capricornus (+0.7 magnitude), will be about 7° west of Jupiter during the month of May. Accordingly, this planet will rise in the southeast approximately half an hour before Jupiter over the entire period and will be low in the south at sunrise. Saturn will reach a stationary point in its apparent orbit on May 9.

The Eta Aquarid meteor shower may be expected on May 4, with a maximum rate of 20 meteors per hour (as seen by a single observer). The moon will be gibbous.

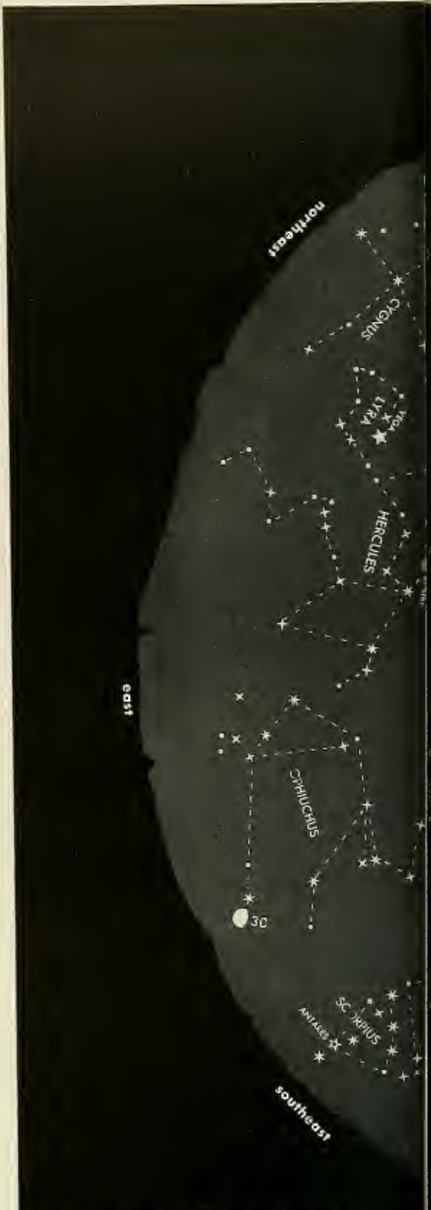
Angular distances:

By convention, apparent distances between stars, planets and other celestial bodies are expressed in degrees and fractions thereof. Although their accurate measurement requires precise equipment, it is often useful to be able to gauge these angles approximately.

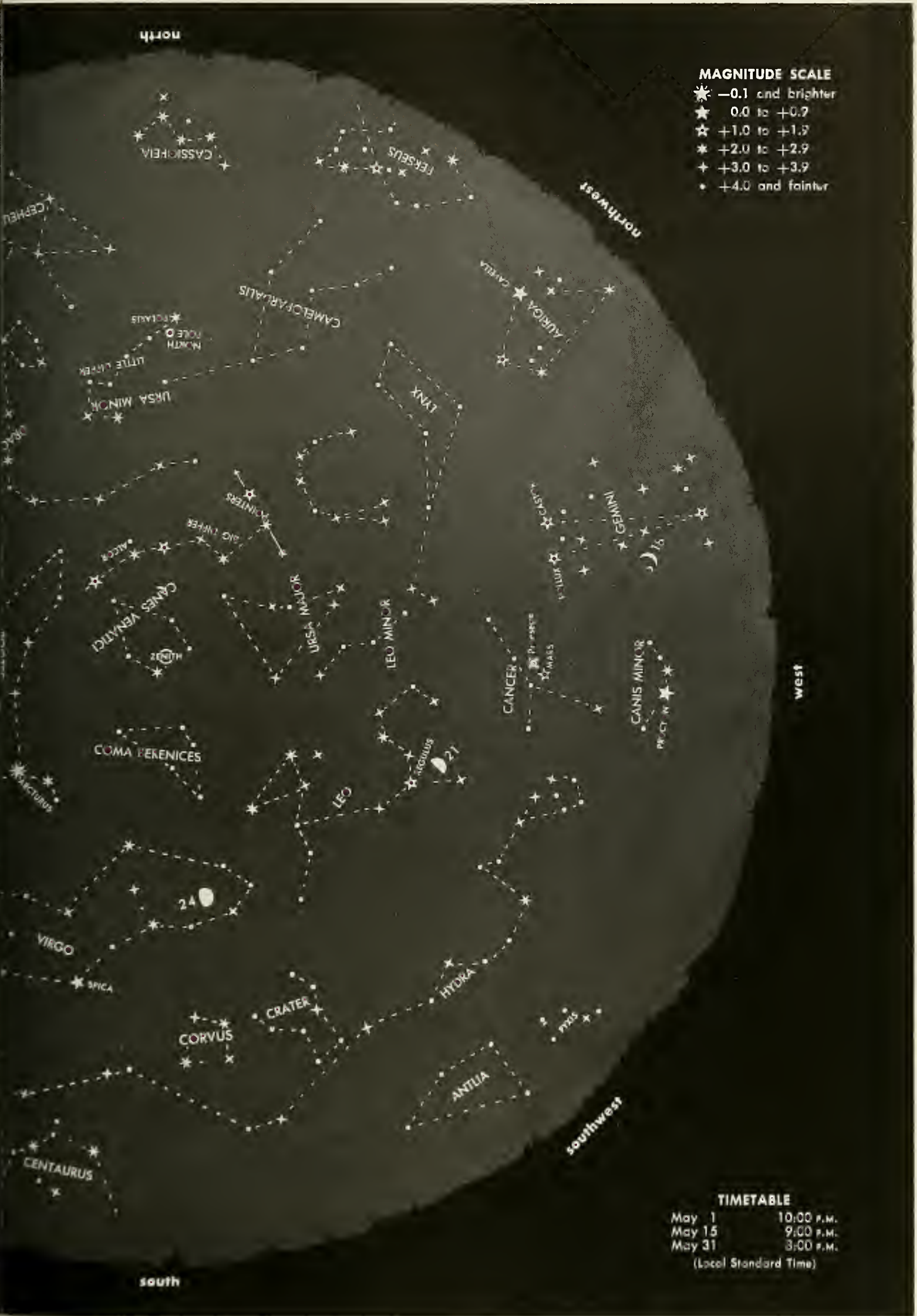
A great circle on the celestial sphere is equal to 360 degrees by definition; thus the angular distance from the horizon to the zenith is 90° or one-quarter of a circle. On that basis, the two stars forming the pointers of the Big Dipper are approximately 5° apart. For smaller angles, it is convenient to remember that the diameter of the full moon is half a degree (in this case, however, one should not use the moon for comparison when that satellite is close to the horizon, because in that position an optical illusion makes it look much bigger than it is).

The observer's own hand may be used to advantage for scaling off large distances. If the arm is fully extended toward the sky, with all fingers outstretched, the angle subtended between the tip of the thumb and the tip of the little finger is equal, on the average, to a span of 22°.

On the preceding pages, MRS. GOSSNER offers the fifth in her 1961 series on the growth of cosmological concepts.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.


north
northwest
west
southwest
south
CASSIOPEIA
PERSEUS
CEPHEUS
CAMELOPARDALIS
POLARIS
NORTH POLE
LITTLE DIPPER
URSA MINOR
CAPELLA
AURIGA
LYNX
POINTERS
BIG DIPPER
ALCOR
CANES VENATICI
ZENITH
URSA MAJOR
LEO MINOR
CASTOR
POLLUX
GEMINI
18
CANCER
PRAESEPE
MARS
CANIS MINOR
PROCYON
COMA BERENICES
ARCTURUS
REGULUS
21
LEO
24
VIRGO
SPICA
CRATER
CORVUS
HYDRA
PYXIS
ANTLIA
CENTAURUS

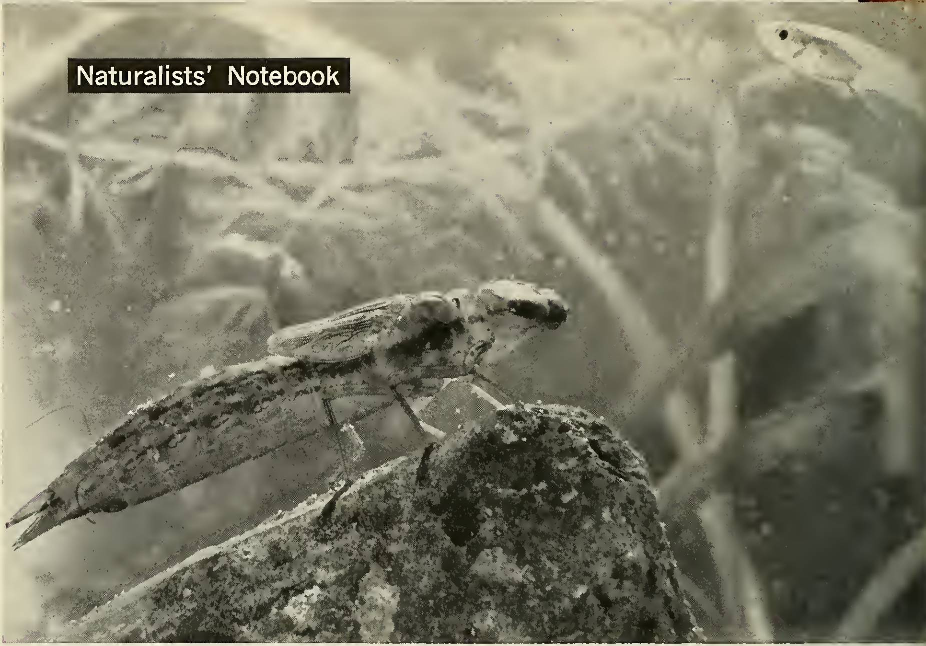
MAGNITUDE SCALE

✸	−0.1 and brighter
★	0.0 to +0.9
☆	+1.0 to +1.9
✱	+2.0 to +2.9
+	+3.0 to +3.9
•	+4.0 and fainter

TIMETABLE

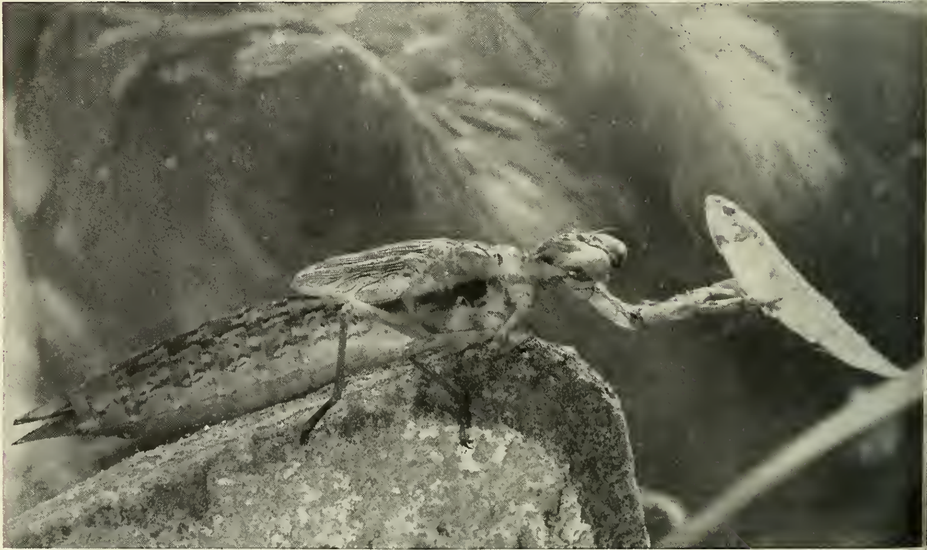
May 1	10:00 P.M.
May 15	9:00 P.M.
May 31	8:00 P.M.

(Local Standard Time)



Green darner dragonfly nymph stands poised underwater, *above*, as it waits for a small fish to come within range. Extraordinarily large, sensitive eyes give the carnivoro dragonfly a considerable advantage in competition for fo

A GREEN DARNER EMERGES



Nymph's labium, or lip, is extended almost faster than human eye can see to seize the fish, securing it with two sharp hooks, *above*. The entire fish will be devoured w n labium retracts to pull prey into nymph's jagged-tooth j s.

MANY INSECTS do not deserve the common names that humans give them, but the dragonfly—boasting one of the most menacing faces seen in nature—would seem to be aptly labeled. Yet, despite its grotesque facial structure and predatory behavior, the dragonfly should be numbered among mankind's benefactors: it eats large numbers of mosquitoes and other harmful insects, and then is eaten in turn.

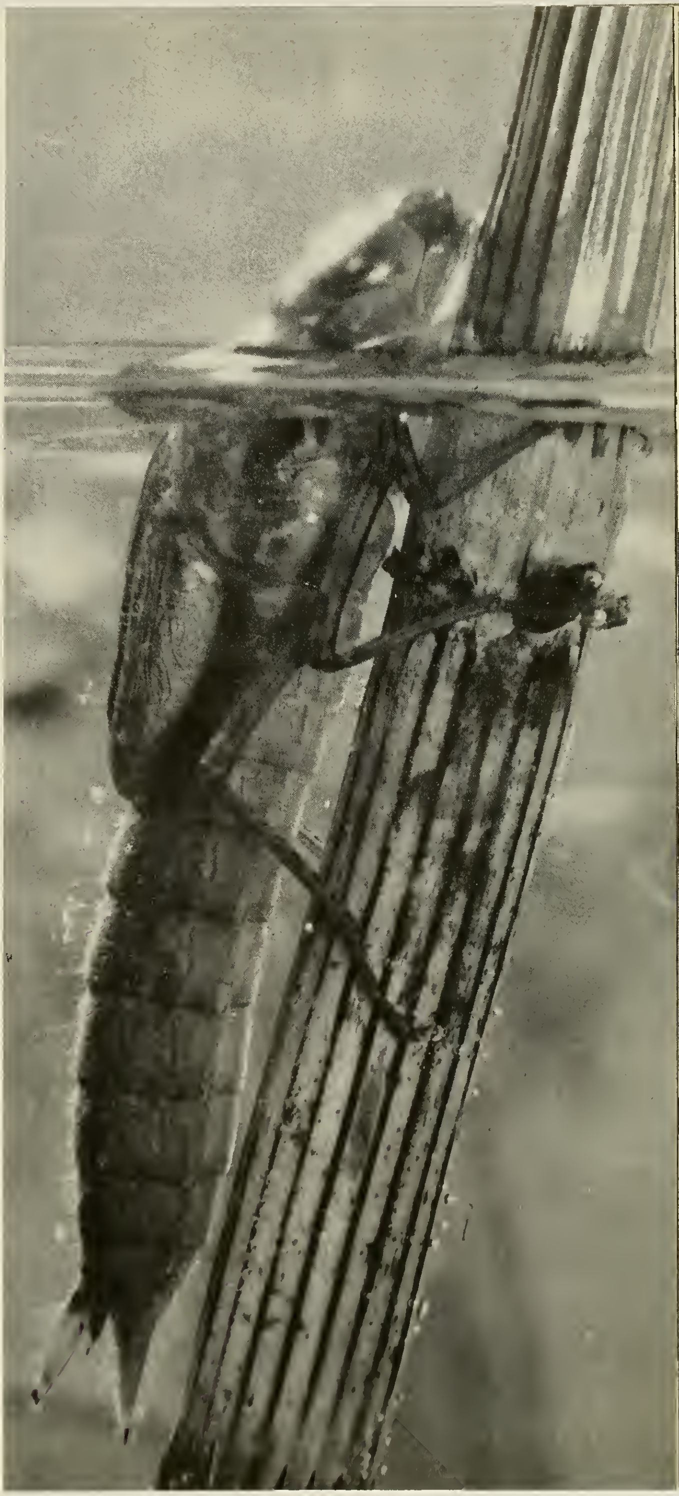
The fact is that the dragonfly long ago secured its role in the balance of nature. Giant ancestors of today's dragonflies—some attained wing spans of thirty inches on foot-long bodies—dominated the skies at a time before flying reptiles or birds existed, while fossil remains about the size of today's dragonflies have been found in rock some 260 million years old. Today's descendants include the 5,000 species of the Order Odonata. One of the argest, fastest, and most brilliantly colored is *Anax junius*, the green darner, familiarly known as the "darning needle." The darning needle is but one of 400 species of dragonflies and damselflies to be found in North Amerca, and although there are numerous variations in the structure, habits, and cycles of these species, all have certain basic similarities.

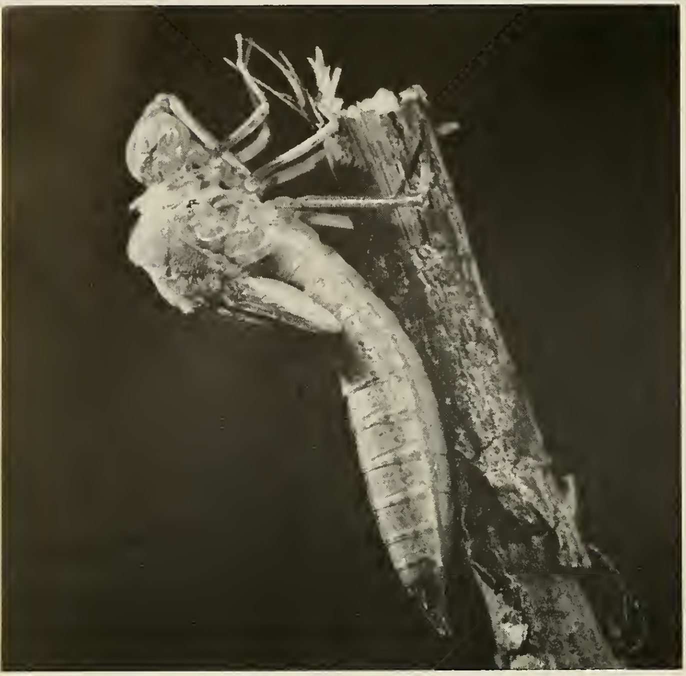
When seen aloft, the darning needle s actually nearing the end of its life, he greater part of which has been passed as an aquatic insect. The female deposits her eggs in waterweeds below he surface by puncturing holes in the stem with her ovipositor. After about wo weeks, the eggs hatch and the econd and longest period of the dragonfly's life cycle begins.

THIS is the nymphal stage, during which the insect dwells on underwater vegetation or sunken logs, feedng on small forms of aquatic life—ncluding other nymphs. As the nymph eeds, it grows; and as it grows, it epeatedly bursts its outer skin. Someimes there are as many as ten molts before the nymph attains full size.

At this stage, a more radical change ccurs. The nymph has been breathng by means of an abdominal gill hamber, but now it must put its head nd thorax above the water in order o breathe (photo, *right*). Shortly hereafter, it climbs entirely out of the water to enter its third and final stage.

AFTER AQUATIC YEAR, the nymph, *right*, eaves water for rest of its life span.





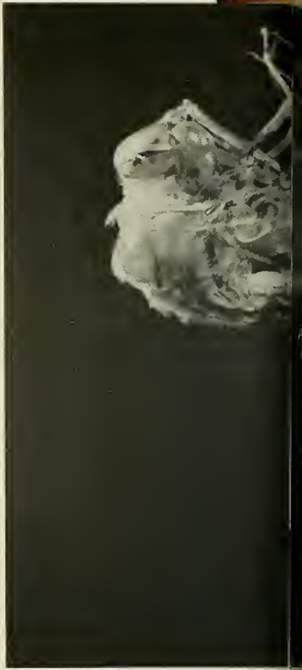
NYMPH'S METAMORPHOSIS begins with swelling of the thorax, *above*. Nymph's legs must be embedded firmly enough to withstand strains that are to ensue.

STRUGGLE TO SUNLIGHT

THE FINAL TRANSFORMATION from an ugly nymph to a shimmering-winged, brightly colored dragonfly may be witnessed all over North America, especially during the warm months of late spring, by close observation of the vegetation at the edges of ponds and streams. The nymph remains quiescent for hours after emerging from the water, while crucial physiological changes occur within it. Then the nymphal skin splits for the last time. This time, a new head and thorax appear through the upper back. Now begins the "birth struggle"—a series of exertions and contortions as the adult dragonfly fights to extricate itself from its nymphal skin.

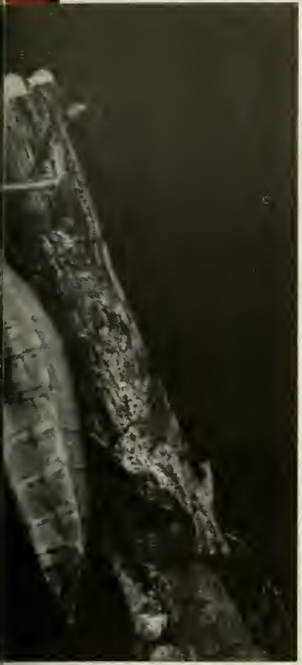
As it emerges, its body is seen to be divided into three parts: the long, slender, segmented abdomen; the thorax, to which are attached the legs and wings: and the head. It is this head that has earned the dragonfly its name: it is a bulging configuration, with antennae, oversized compound eyes, and flexible lower lip, or labium, with jagged-tooth jaws just visible. The main pair of eyes, alone, would give the dragonfly an advantage in its brief existence. These huge organs are each composed of as many as 20,000 sight units, while three other single eyes are situated on the upper surface of the head. Together, they allow the dragonfly to see in all directions at once and to detect motion as far as fifty yards away.

The wings of the dragonfly are its most spectacular feature. As they are pumped up, intricate patterns of veins are revealed—patterns sufficiently differentiated to enable us to distinguish and classify the various species. For the adult dragonfly, its wings represent life itself. Rain, wind, or clouds may occasionally drive it to shelter, but otherwise the green darner spends most of its life on the wing—darting and hovering, preying and eluding—the gauzy-winged insect known to us. Finally, the male and female will mate in flight, and after the female has deposited the eggs in some reed at the edge of a pond or stream, the dragonfly's life cycle will start in anew.

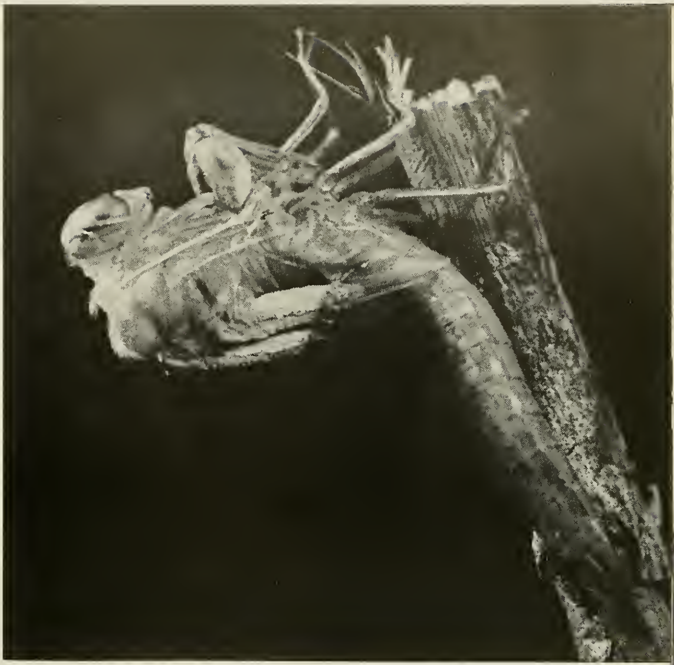


Hard cuticle of the nymph's shell spli
along the back and the adult begins

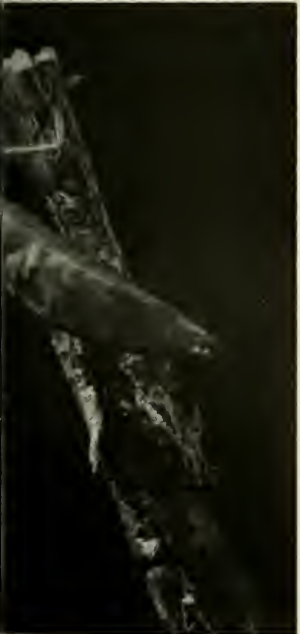
After much struggling, the dragon
has freed most of its abdomen, *abo*



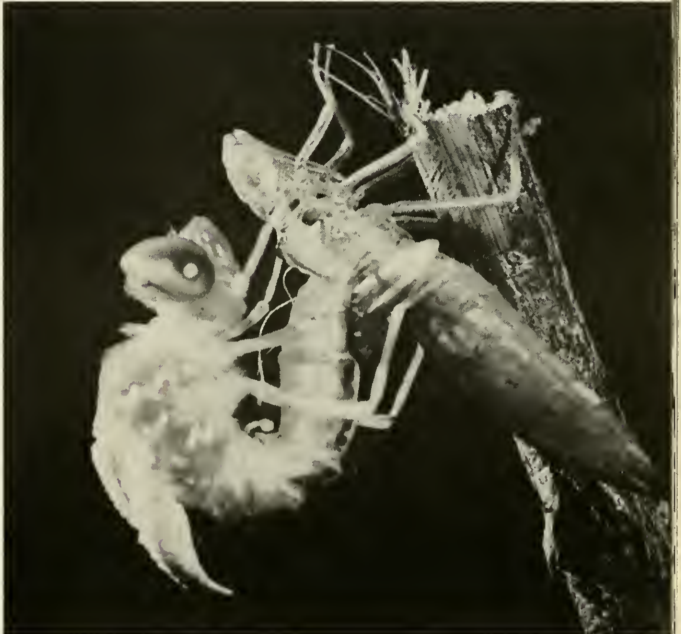
emerge, *above*, as the first stage in the exhausting struggle to extricate self.



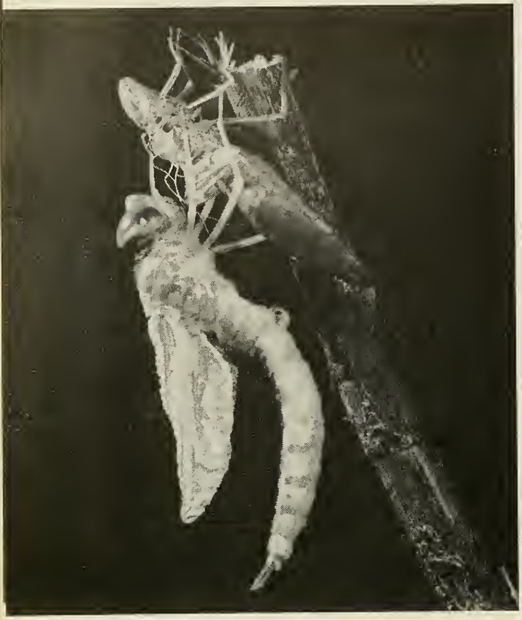
Head and thorax of the adult insect are now clearly free of the old skin, *above*. Note the moist, crumpled wings as they emerge from the old wing cases.



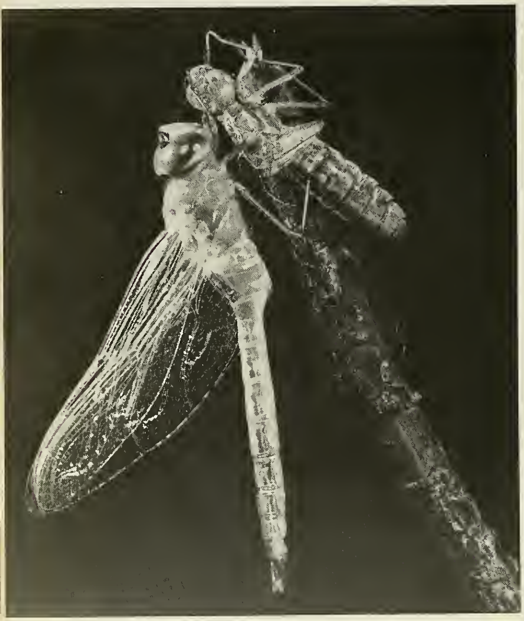
It dangles for a while, head down and throbbing, debilitated from exertions.



Revivified, the dragonfly now arches its body back to cling to the head of the nymph case, *above*, for a final effort at freeing last segments of its abdomen.



EXHAUSTED DRAGONFLY rests its damp body, *above.* As blood circulates, *below,* wings expand; color changes take place.



ADULT GREEN DARNER spreads out its finely veined, gossamer wings, *right,* before embarking on a brief aerial existence.

The Surinam Toad

Pipa pipa's aquatic ballet implants eggs in female's bac

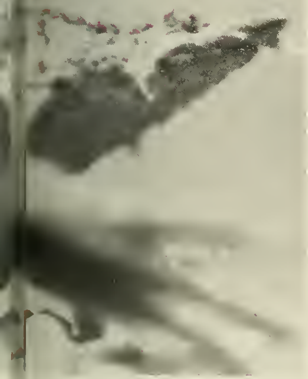
By George Rabb

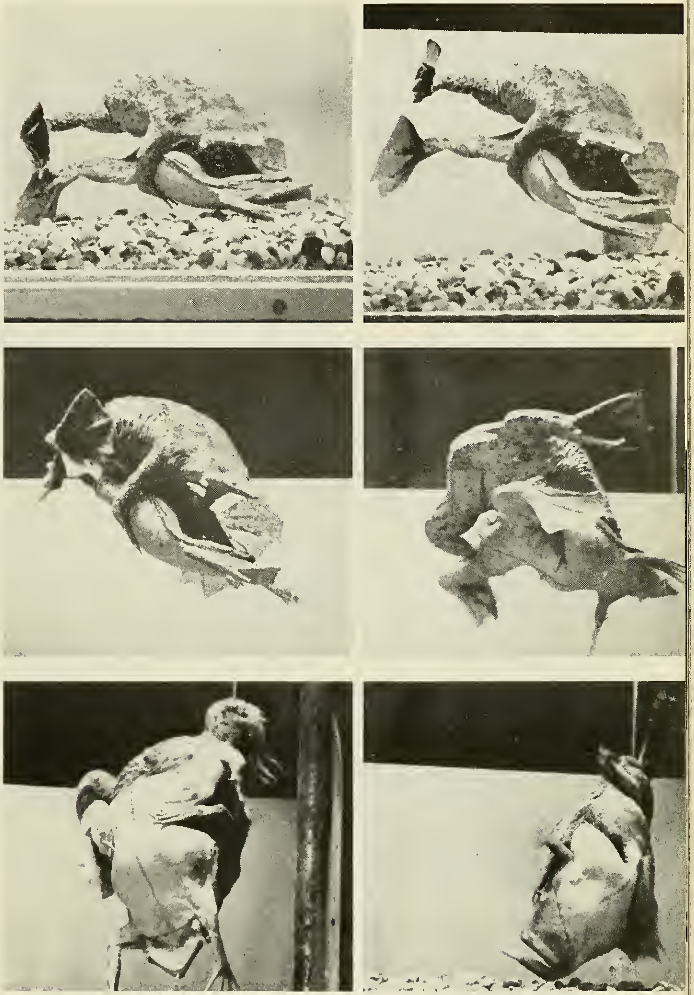
The life history of our common frogs follows a familiar course. Typically, frogs lay numerous small eggs in ponds or streams. The eggs develop quickly into the large-headed, long-tailed, limbless, aquatic larvae we know as tadpoles or polliwogs. After a growth period that lasts for a few weeks (or even several summers, as occurs with the bullfrog), the tadpole transforms. Practically all the body parts change at this time, and the result is a miniature of the adult frog, equipped for life on land.

Since the defenseless eggs and young are food for many predators, it seems that only by producing great numbers of eggs can most frog species maintain their populations. As with other cold-blooded vertebrate animals, however, there have been trends toward apparently "safer" ways of development among frogs. Thus, the aquatic larval stage has been eliminated or shortened in some species in most of the families of frogs. Each of these departures from the typical mode of frog development seems to have come about independently, and there is thus a variety of approaches to this period of early development to be observed.

Only a few of these odd breeders occur in the northern part of the world. Such a one is the midwife toad, *Alytes obstetricans*, of southwestern Europe. The male of this terrestrial frog carries the eggs entwined about his legs during their early development. Later, he backs into a pond to release the tadpoles. In southern Florida, the greenhouse frog, *Eleutherodactylus ricordi*, and in Texas another *Eleutherodactylus* and two species of the related genus *Syrrhophus*, lay their eggs on land. The entire development of the young takes place within large-yolked eggs, which may be guarded and perhaps kept in a moist state y one of the parents during the o months that precede hatching.

Most of the oddities are founc n the Tropics and farther south. Am g them are the marsupial tree fr gs *(Gastrotheca)* of South America at carry the young in a deep pocket n the mother's back skin. The yo g emerge as froglets or tadpoles. epending upon the species. Even n re interesting are two species of s ll African toads *(Nectophrynoides)* at give birth to fully developed yo g. The pregnancy resembles that of s e viviparous reptiles. Observations re still needed on the fertilization ocess in these toads. Another fasc iting breeding habit is that of Dar 's frog, *Rhinoderma darwini.* The le of this small, brightly colored sident of southern South America irries the offspring about in is enlarged vocal pouches!

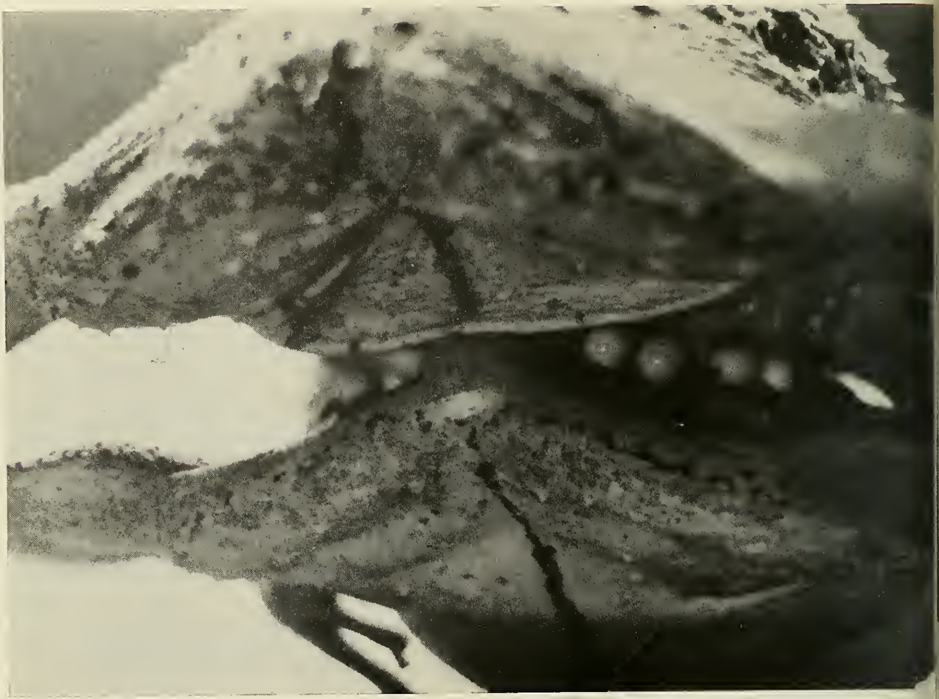




RINAM TOADS, *above*, clasp several ours before egg-laying. The sequence right, reading left to right, top to ottom, shows the intricate aquatic aneuvers of pair as female lays eggs id the male presses them to her back.

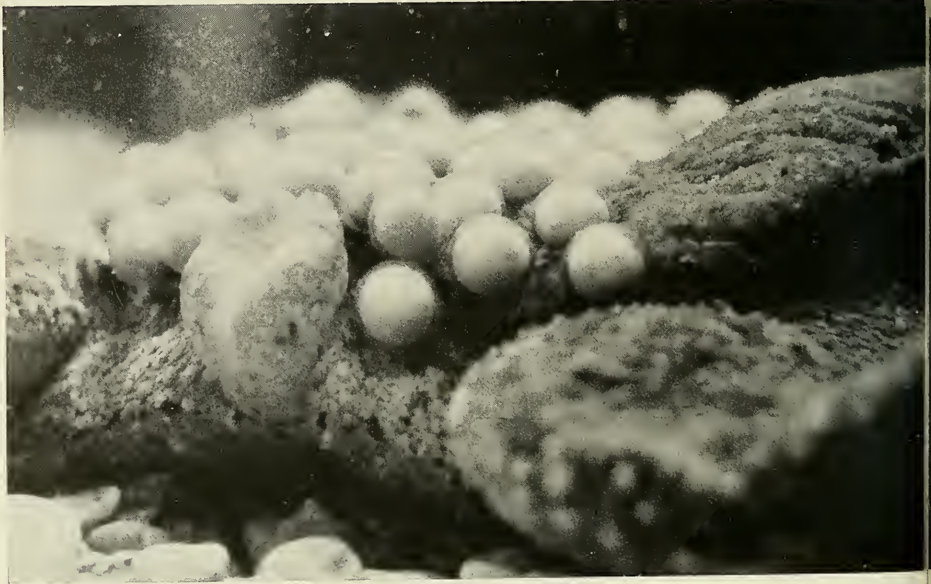
Perhaps the most widely known of iese exotic frogs is the Surinam toad, *ipa pipa*. Its habit of carrying the ung in individual pits on the moth- 's back has been written about for ore than 250 years, and the general itline of its embryology has been iown for nearly a century. This toad found over a large part of northern outh America, from Trinidad and the uianas to northeastern Peru. It be- ngs to a primitive family of frogs Pipidae) that has members in Africa well as South America. In all five outh American species (but not in e African forms), the female frog ars the eggs on her back. In two of ese egg-carrying species, the young erge as well-developed tadpoles id in the other three as froglets.

F all the family, the Surinam toad is the most peculiar and ecialized. It is one of the largest of



Male toad, *above,* exhibits temporary fold in belly skin as he presses eggs to female. Fold forms when body arches.

Imbedded eggs on female's back, *below,* rest near
vent. Tumid skin and inflated lung cause swelling at ri



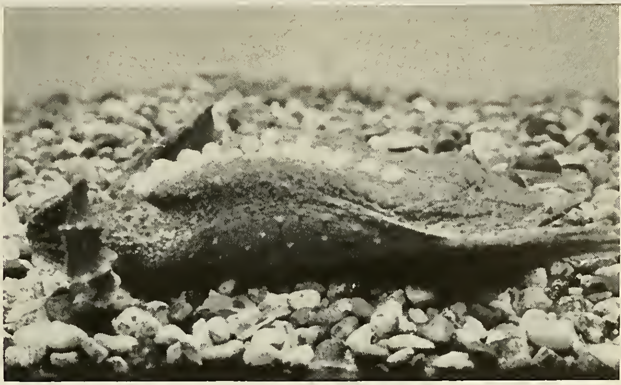
DR. RABB, Curator of Research at the Chicago Zoological Park, made this study of *Pipa pipa* in concert with his wife, Mary, and with the Curator of Reptiles, Mr. Snedigar.

ll frogs, sometimes attaining a body ength of eight inches and a weight of bout one pound. So far as is known, t is wholly aquatic. The large, fully ebbed feet and powerful hind leg nuscles are well adapted for swim- ning. Another obvious adaptation or an aquatic existence is the reten- ion of parts of the "lateral line" ystem—the pressure- and direction- ensing network in the skin of fish and quatic amphibian larvae. The body tself is very flat and the gape of the oad's toothless, tongueless mouth s enormous. The animal's bizarre ap- earance is enhanced by skin fila- nents that dangle from beneath the mall, lidless eyes and the snout, and lso by the larger, loose skin flaps at- ached to the sides of the head. Even he long fingers are odd: their very ensitive tips are forked into several obes. The color of *P. pipa*'s upper side s usually gray, with darker brown- sh or blackish blotches. Fairly rapid hifts in color shade are made on asion, especially when light condi- change. The underside is mostly hite, but in many specimens a large, -shaped, dark marking is noticeable n the chest and the belly.

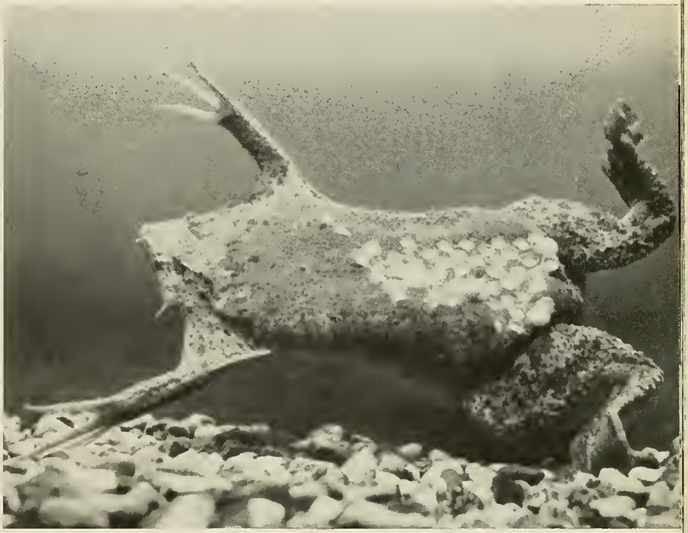
REPRODUCTIVE habits of the Surinam toad have long been a mys- ery despite the fact that the species ill breed in captivity. At the Brook- eld Zoo two years ago, we received a ew specimens captured in a tributary f the Amazon River in Colombia. ince then, one pair has bred twice. he following description is based ainly on observations of this pair.

When a male is in breeding condi- ion, he makes a series of sharp, click- ng noises. The sound is not unlike hat of a coin tapped on an aquarium all. In fact, such tapping will often roduce a response by a male. Unlike ther frogs, which make their breed- ng calls by vibrating the vocal cords nd using throat pouches for amplify- ng chambers, the male Surinam toad akes his call by "popping" or slip- ing a joint in a bony voice box. The licking noise carries well through ater and the sound probably would ttract a mate in the wild.

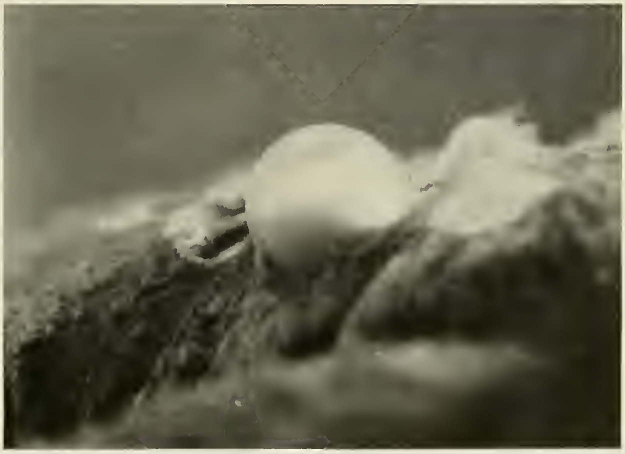
A female ready to breed will allow

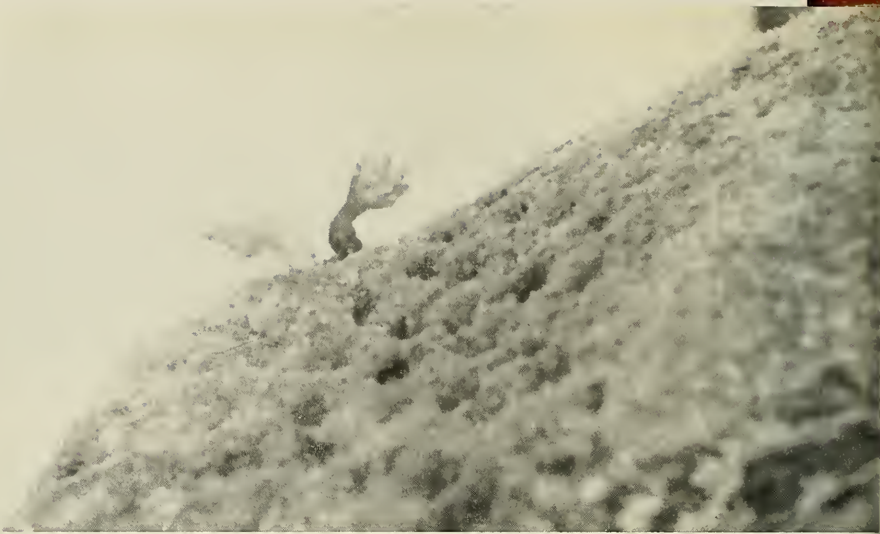


FEMALE'S BACK is covered with eggs, *above*, late on first day after mating. By third day, *below*, eggs have begun the process of sinking into the skin.



PROTRUDING EGG shows above skin of back, *below*, on eleventh day. The egg was aborted, as are all eggs that do not recede flush with surface of skin.





YOUNG TOAD STRETCHES ITS LEG from a pocket on mother's back on sixtieth day after egg was laid. Its dwindled tail appears near leg. The tail is normally resorbed at lea three weeks before young frog emerges from mother's bac

the male to grip her firmly about the lower part of her body. If she is not receptive, she quivers until released. In our aquarium, a male will make mistakes by grasping at freshly fed females, which resemble egg-laden ones in their stoutness. He is soon informed of the actual situation.

IF the female is ready, the clasp is maintained for more than a day. During this time, the skin on the female's back becomes puffy as the blood supply to it is increased. The male occasionally tightens his arms abruptly, perhaps thereby stimulating the release of eggs from the ovary to the oviduct. When egg-laying is near, the pair begins to turn over repeatedly in the water (illustrations, p. 41). This action, effected mostly by the female, consists of a half-roll and a half-forward somersault. First there is a rising rotation about the long axis of the body, a momentary pause in the resulting inverted position, and then a descending rotation about the transverse axis of the body.

This maneuver was puzzling at first, but the role that it plays became evident when the first egg was laid. The egg popped forth in the middle of a turnover while the pair was upside down in the water! In most productive turnovers, 3 to 5 eggs are laid, and the total number ranges from 40 to more than 200. As the eggs emerge they are more or less caught by the male's belly and its temporary anterior and posterior folds of skin. As the pair flips over and returns to the bottom, the eggs drop onto the back of the female and adhere there as the male fertilizes them.

The entire turnover process takes only eleven to fourteen seconds, and the expulsion of the eggs must be synchronized with the mid-turnover pause—about one second in duration. Otherwise, the eggs fall to the bottom and are lost. We recorded 20 per cent losses from mistiming. During the upward movement of the turnover, we noted that the male moves his fingers against the belly of the female, perhaps stimulating or helping her to expel the eggs a second later.

The contact of the expelled eggs against the male apparently induces him to relax his grip and emit seminal fluid as the pair descends. When he tightens his clasp of the female again, he usually presses the newly laid eggs more deeply into the skin of her back. The eggs themselves have no sticky quality. When all eggs have been expelled, the female indicates that she has finished by quivering. Then the male releases her.

The development of the eggs—each about a quarter of an inch in diameter—is a slow process. They sink gradually into the skin of the female's back, becoming flush with its surface on about the tenth day. Some eggs are crowded out and lost during this period. The outermost egg membrane forms a cap for the skin pocket, or cell, in which the egg develops. Tl cap is soon covered with debris, that it is difficult to see what is ha pening to the egg. Even so, eye pi ment and ear stones are evident the end of the second week.

By the middle of the fourth we the embryo is able to move quick within its brood pocket and will do in response to bright light directed the eyes. Although the young do go through a tadpole stage, they possess a tail during growth, wh probably provides a surface for o gen exchange with the walls of pocket, which are richly suppl with blood vessels. The tail is sorbed at least three weeks before young leave the mother's back. place as a probable respiratory org may be taken both by transparent sue that protrudes temporarily fr the vent of the young and by the r tively large skin flaps at the side of jaws. Judging from dry weights of young and eggs, there does not se to be any passage of nutriment fr the mother to her offspring.

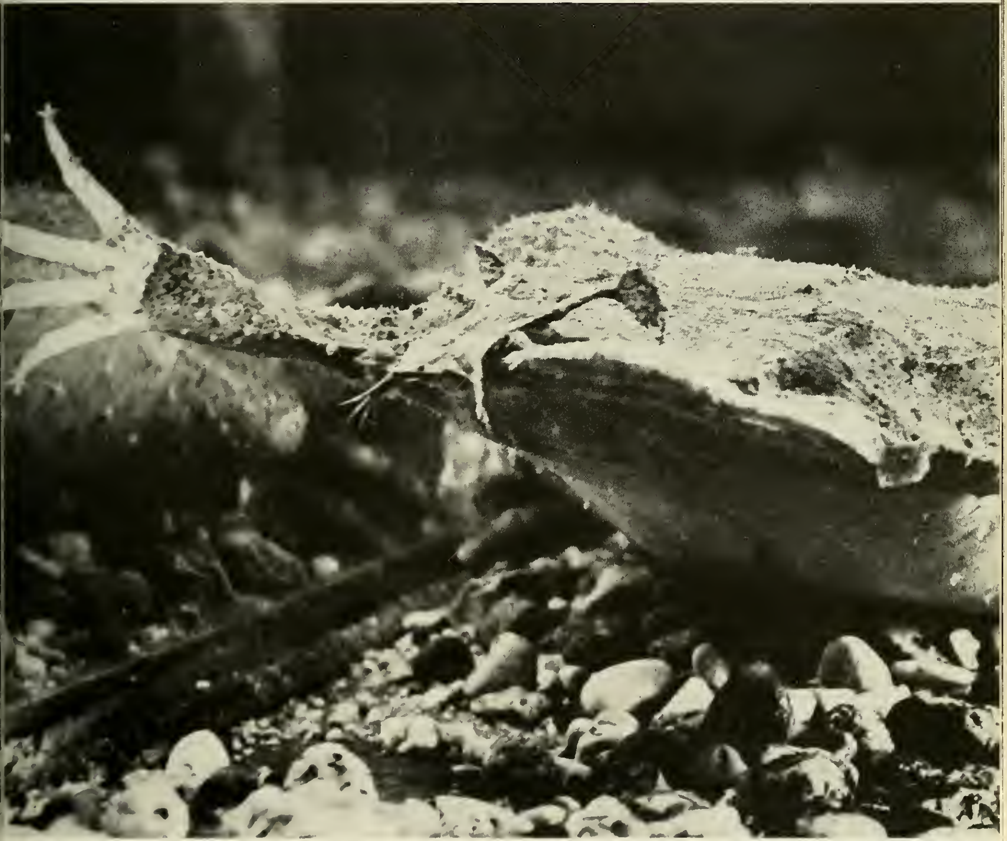
THE emergence date for our fr lets varied from 77 to 136 d after egg-laying. Emergence se related in part to skin-shedding by mother. In both observed breedi some young were lost at the end of second month, when the mother sl The aborted young at this stage had a great mass of abdominal but had resorbed the tail.

Cell caps are often lost in the first shedding, and the young may then put legs, arms, or snouts out of the opening. If the female sheds again, the young are apt to leave: the shed skin of the pocket walls probably hinders oxygen exchange. The mother also has an active role in ridding herself of the young. She exerts internal pressure that forces the young partly from their pouches for a minute or two at a time. Eventually the froglets seem to respond to this and pop out under their own power, to swim to the surface. The newly emerged young are tiny, compared to the adults: they average about three quarters of an inch in ength and only a little more than a enth of an ounce in weight.

The young stay at the surface of the water most of the time for the first month or two after emergence. At first they have difficulty adjusting their buoyance for diving. They feed quickly in a recoil action common to other members of the family: a sweeping grab when food comes close or touches the hands, and an instantaneous backward thrust of the body.

When the young of the first brood poked their heads and legs out of their pockets, we attempted feeding them. They responded vigorously to small, wiggling worms that were dropped onto the mother's back.

A matter not easy to understand is that the mother does not eat her free-swimming young. Ordinarily, any small, moving object touching a Surinam toad's fingers is swept into its mouth, but this has not happened to the young *Pipa pipa* that have so stimulated their mother. We thought this immunity might depend on the female's sight, and so we removed the young of the first brood from the mother's aquarium to prevent mistakes during the night. However, the young of the second brood have been left with the mother for more than two months as this article is written, and no harm has come to them. It may be that, in the evolution of the Surinam toad's odd brooding care, this curb on the mother's normal feeding behavior was brought about by selection: the mothers who snapped up their young would necessarily leave few offspring compared to mothers who refrained.



NEWLY EMERGED FROGLET flops over its mother's right eye. Young have emerged anywhere from 77 to 136 days after the eggs were laid. They pop from cells with a maternal assist as the female exerts internal pressure to force them out.

Part II

Life in the Scub

Zone

Diet and form are the keys to population densities in the shallow, offshore waters

By Willis E. Pequegnat

The nature of the sea bottom exerts an important influence upon the distribution of the benthos—all bottom-dwelling, marine animals. This fact is recognized by a division of all such marine life into two great groups—the epifauna (which inhabit rock and other hard substrata) and the infauna (dwellers on soft, level bottoms). Even though the epifauna occupies only about 10 per cent and the infauna the remaining 90 per cent of the world's sea bottom, roughly more than four times as many epifaunal than infaunal species have been described up to the present.

The competition for space among epifaunal species that develops from these ratios leads to population densities that stagger the imagination. My associates and I were introduced to this epifaunal complex by a study of a few of the species that crowd upon siltstone reefs in the relatively shallow waters of the California shore southeast of Newport Harbor. We have already described the series of zones that reflected the changes in density of the organisms that dwelt from the top to the bottom of the two reefs we studied (Natural History; April, 1961). As pointed out there, the nature and distribution of food cannot be overlooked as a major factor controlling the ecology of these bottom-dwelling marine animals.

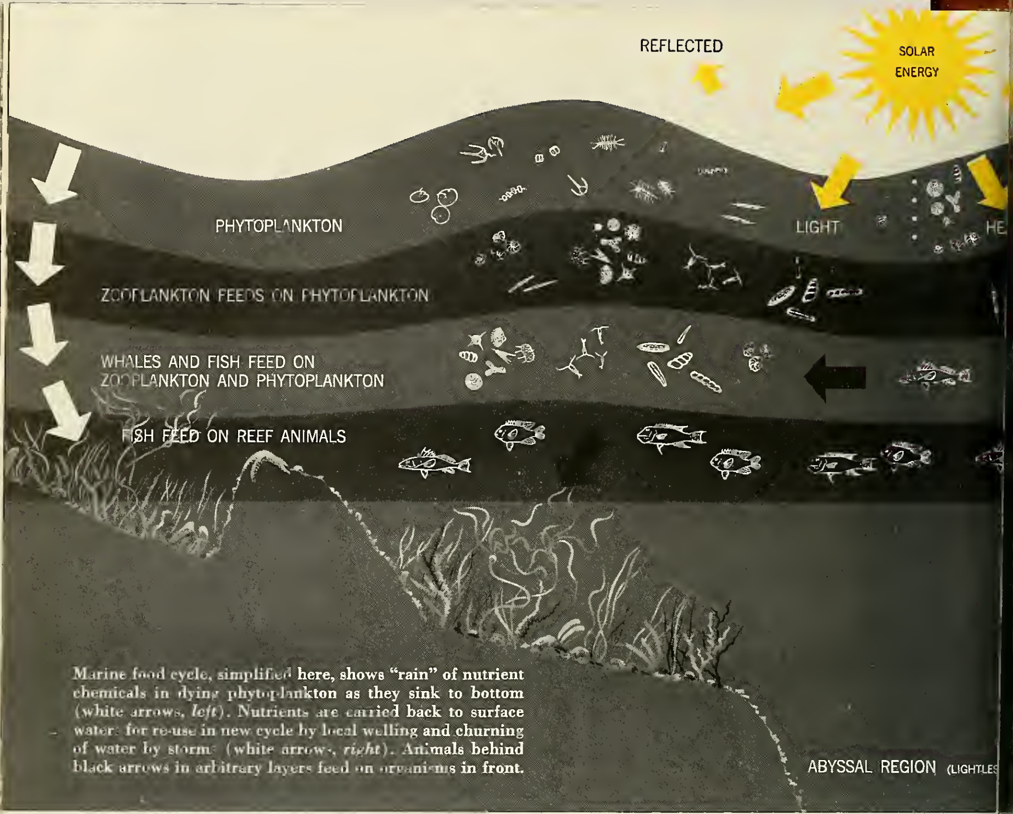
If the nature of the substratum is of first importance in controlling the *general* distribution of benthic organisms, then food availability runs a close second, since food supply and variety will determine more *specific* regions where various species may exist and also will control, in part, the size of various populations. It is important to note that obtaining food is the task for which animals may exhibit the highest order of structural adaptation. An understanding of these adaptations is needed before we can explain how epifaunal species can exist under such crowded conditions.

Spiny lobster roams reefs at night, consumes fixed and slow-moving bottom animals as well as fish, live or dead.

If we conceive of the mass of animals existing on submarine reefs as a great machine, it follows that such a machine will function properly only as long as "fuel" in the form of usable food is poured into it. This machine and its physical environment form a biophysical complex, or ecosystem, in which populations of organisms grow and decline, and through which matter and energy flow in a series of transformations and degradations. Where does the energy come from in the first place? Most of us are aware that the prime energy source on land is solar radiation, but many have only a vague conception of the role it plays in the energy cycles of the sea. Let us explore briefly the path between the penetration of sunlight into the water and this radiation's appearance on submarine reefs as food energy. It will be evident then that the epifauna of our reefs cannot exist apart from the inhabitants of the surrounding water (pelagic organisms) and adjacent, level bottom (benthic infauna).

Five major categories of food are available in the sea. In probable order of importance to epifaunal animals these are: (1) suspended organic matter (including living plankton and small, non-living organic particles) before it has settled to the bottom; (2) deposits of organic matter (detritus and small, benthic organisms—particularly bacteria—that form a film or scum on the bottom); (3) organic debris meaning those larger pieces of organic matter that derive from destruction of relatively large plants and animals); (4) the larger living animals; and (5) plants of the fixed type (including seaweeds and kelp, and those that form low mats over rocky surfaces).

To take the last category first, surprisingly few marine animals feed directly upon seaweeds and kelp. Among them are the molluscan sea hare, *Aplysia* and the smooth turban snail, *Norrissia*. However, a larger number of species—many of them


REFLECTED
SOLAR ENERGY
PHYTOPLANKTON
ZOOPLANKTON FEEDS ON PHYTOPLANKTON
WHALES AND FISH FEED ON ZOOPLANKTON AND PHYTOPLANKTON
FISH FEED ON REEF ANIMALS
LIGHT
HE
ABYSSAL REGION (LIGHTLES

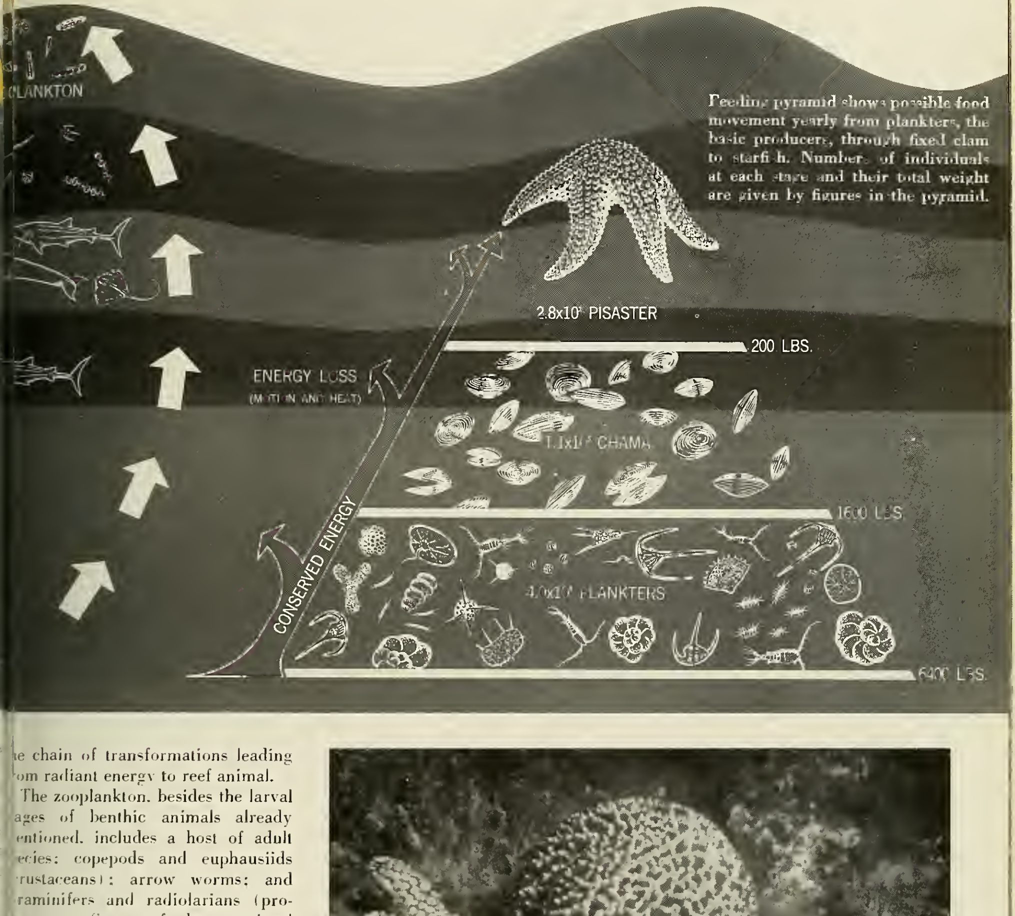
Marine food cycle, simplified here, shows "rain" of nutrient chemicals in dying phytoplankton as they sink to bottom (white arrows, *left*). Nutrients are carried back to surface water for re-use in new cycle by local welling and churning of water by storms (white arrows, *right*). Animals behind black arrows in arbitrary layers feed on organisms in front.

epifaunal—feed upon smaller algae. Some limpets, periwinkles, and chitons, for example, scrape these algae from rock surfaces with a filelike structure in the mouth. Yet, the relative unimportance of these algae as direct contributors to the sea's food cycles is somewhat unexpected considering the major role that plants play on land in transforming radiant energy into chemical potential energy by uniting carbon dioxide and water into carbohydrates. Here, however, we must emphasize the phrase "as direct contributors." Much of the organic matter of seaweeds is *not* wasted since, upon death, their substance contributes to the sea's stockpiles of detritus and debris.

GRASSES are the great photosynthesizers on land. In fact, man's economy is based everywhere upon the ability of domesticated and wild grasses to provide an abundance of cereals and livestock forage. A host of hoofed animals, and even rodents, are adapted to ingesting wild grasses. True grasses do not exist in the sea, but it is obvious that something analogous to them must take their place. That something is found in the complex assemblage of organisms included in the term plankton, which lies suspended in the upper layers of sea water. The importance of plankton to sea animals is evidenced by the fact that plankton feeds not only myriad small marine animals but also the largest whales and fishes.

Plankton is no taxonomic term, but an ecologic one comprising a complex of hundreds of plant and animal species. Some animals exist solely as plankters: others join the plankton only in the egg and larval stage, eventually transforming into adults. These adults then remain in the free water, as with fish (NATURAL HISTORY, May, 1959), or settle to the bottom, as with such epifaunal or infaunal species as barnacles, starfish, or clams. Although diversity is the hallmark of the plankton, there are a few characteristics plankters share in common. All have developed some device that permits them to remain suspended in the water. Most are passive floaters, drifting with the currents, for even the strongest swimmers among them can seldom breast the currents for long. Finally, most plankters—at least the important ones for our purposes—are small, being either microscopic or measurable in a few tens of millimeters.

THE two great subgroups of plankton are the phytoplankton (plant component) and the zooplankton (animal component). The phytoplankton designates all plankters that possess chlorophyll, and thus photosynthesize. The most important of these are the minute, unicellular diatoms and dinoflagellates, both of which may be classified as algae. These phytoplankters use the sun's radiation to synthesize carbohydrates and other organic compounds. Thus in these minute algae is found the first link in



Feeding pyramid shows possible food movement yearly from plankters, the basic producers, through fixed clam to starfish. Numbers of individuals at each stage and their total weight are given by figures in the pyramid.

he chain of transformations leading
om radiant energy to reef animal.
The zooplankton. besides the larval
ages of benthic animals already
entioned. includes a host of adult
ecies: copepods and euphausiids
rustaceans): arrow worms; and
raminifers and radiolarians (pro-
zoans). Some of these animal
ankters feed directly upon the phy-
plankton; others eat fellow zoo-
ankters. Hence there are food cycles
ithin the plankton itself. In addi-
on. tremendous quantities of both
oups are consumed by epifaunal
d infaunal species as currents carry
e plankton along. while a steady toll
taken by fishes. birds. and baleen
hales. Those plankters that escape
rect consumption eventually die.
ttle to the sea bottom. and add to
e debris and detritus. And the same
d lies in store for all the organisms
at feed upon the plankton.

Dead organisms. plant or animal.
ldom remain untouched in the sea.
wave zones they are soon broken

FEEDING STARFISH bumps body to help suckers part clam's shells. When a gap develops, starfish drops stomach into clam, digests soft parts with enzymes.

Dr. Pequegnat, Associate Program Director with the National Science Foundation, concludes here his study of the Scuba Zone, which started in last month's issue of this magazine.

into pieces of various sizes. Beyond the waves, carcasses are torn by fishes, scavenging crustaceans, and sea urchins. Thus, although seaweed and kelp are little used as food when alive, they are so used when the alga is destroyed. Large fishes, which in some instances actually feed upon anchored reef animals, will be transformed upon dying into food that can be eaten by their former prey. Carcass fragments that escape consumption as debris accumulate where bacteria, protozoans, minute crustaceans, small worms, and various larvae attack the dead tissue by enzymatically reducing it to compounds that can be used by a wide variety of animals. This decaying mass, including minute, attacking organisms, is called detritus. It forms a scum of organic matter over the surface (and even in the interior) of the substratum. Here it will be fed upon by larger animals, or it may be picked up by currents and carried long distances before it settles on reefs or the level bottom. En route, part may be used by suspension-feeders: when it reaches its final destination, it sustains a host of clams, worms, and sea cucumbers that dwells on the bottom and feeds on the accumulated detritus.

It is apparent that here we have outlined still another path taken by radiant energy from its penetration into the water to its appearance on the reef as food energy. The seaweeds intercept part of the sun's radiant energy and, like the phytoplankton, thereby create organic materials. When the plant dies, part of the tissue becomes debris, to be consumed by scavengers. Dead scavengers—and any remaining plant tissue—will be fed upon by bacteria and other minute creatures, which create detritus while using energy released by the decomposition of the plant and animal tissue. But this process is not self-sustaining. The conversion from alga to bacterium to clam, say, is never more than 20 to 30 per cent efficient at each step. It is evident that this is a downhill series of conversions, maintained only by the constant addition of radiant energy from the sun.

Because most of us are familiar with predator—prey relationships, it is unnecessary to discuss the category of food we call "the larger living animals." One such relationship is described quite fully, later.

Let us now consider the kinds of animals that are adapted to nourishment from these various food types. Those that use suspended matter are called suspension- or filter-feeders. Deposit-feeders find their sustenance in detritus. A scavenger attacks debris. The carnivores feed upon the larger animals, and the herbivores feed upon the fixed plants.

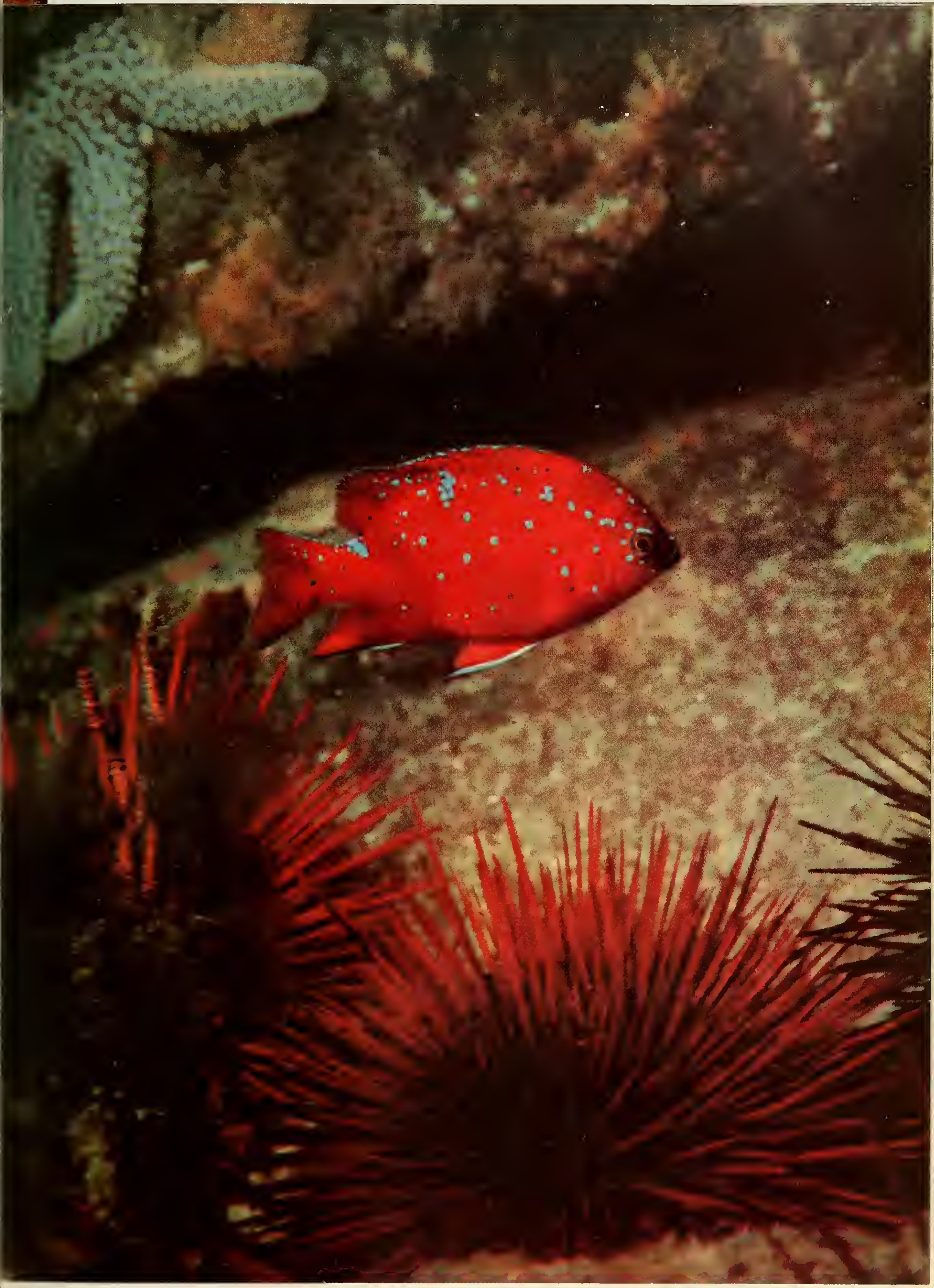
Since all five classes of food are available to both epifaunal and infaunal animals at some point in their distribution, it follows that the five feeding adaptations will occur in both groups as well. But there are general differences between the two groups regarding frequency of occurrence of suspension- and detritus-feeders. It seems likely that the majority of epifaunal species are filter-feeders, followed in numbers by deposit-feeders. Apparently, except in local situations, the reverse is true among the infauna. It is possible that whether filter-feeders or deposit-feeders predominate in local, infaunal situations is determined by the relative water movement and orientation of currents. Where water movement is slow, fine organic silts collect—usually rich in detritus—supporting relatively dense populations of deposit-feeders. Increased water movement creates coarser bottom deposits that are usually detritus-free. But such turbulence or current action may bring more suspended matter into the area, permitting a predominance of suspension-feeders. Essentially the same relationships occur in the epifaunal domain.

Unfortunately, we do not know enough about the habits of many epifaunal organisms to state positively the relative rank of the three other feeding types. The information we do have points to nearly equal numbers of scavengers and carnivores (the latter slightly in the lead), while herbivores come in a poor fifth. Essentially the same is true of the infauna, although here the gap between carnivore and scavenger may be greater.

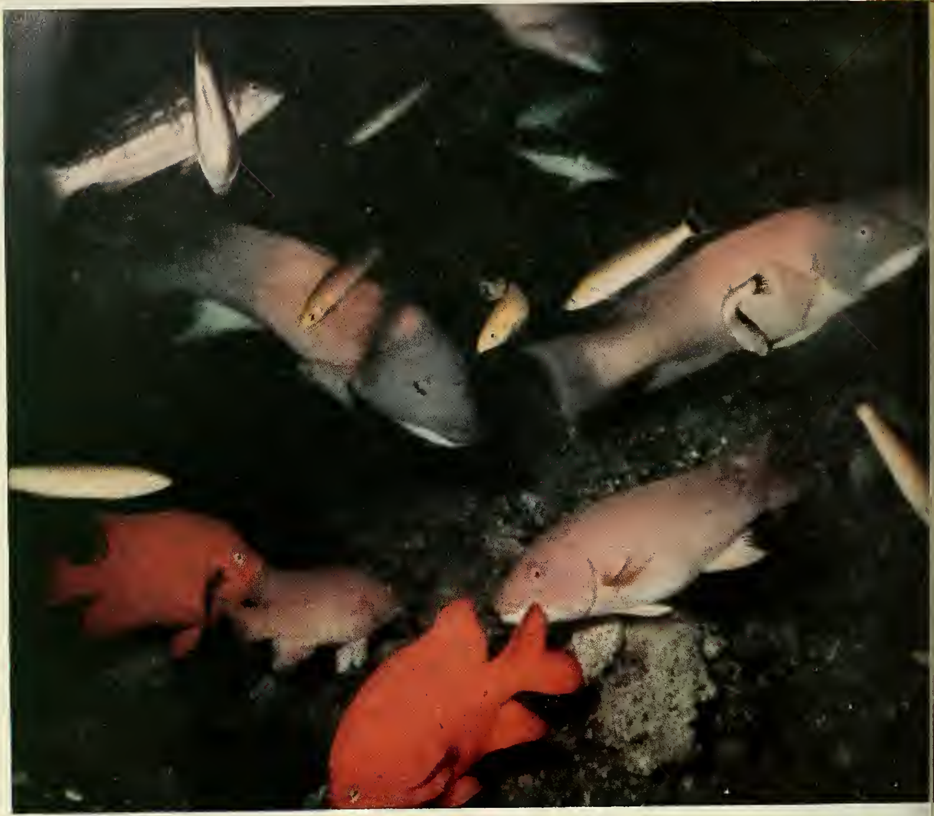
An animal's structure reflects the kind of food it eats. The greatest structural modifications we find among epifauna are those of suspension- and deposit-feeders, and there are close parallels between them. T method of removing suspended par cles from water often depends, fir upon minute, hairlike cilia for cre ing microcurrents and, second, up mucus for holding particles wh they are carried to the mouth.

Perhaps the most elaborately dev oped suspension- and deposit-fee ers are bivalve mollusks. They ha complicated, porous gills, which fu tion less as respiratory organs th as active, food-catching sieves. Al they usually have a pair of large, le like structures near the mouth, call labial palps. Both gills and palps crossed by numerous ciliated trac grooves, and mucous strings, whi transport usable food toward mouth and reject unsuitable particl The cilia can create noticeable c rents: thus bivalves can live in de aggregations and still pump am supplies of suspended matter acr their gills. Obviously, this method feeding will permit bivalves to b row into the substratum, be it rock sand, and still feed upon plankton detritus, provided their siphons h direct or indirect access to the s face. Detritus-feeding bivalves similar to the suspension-feeders, cept usually they have a compa tively long, mobile siphon that su up detrital film and carries it i water stream to the gills, where usual separation takes place. Asci ans, or sea-squirts, are suspensi feeders that use essentially the sa method as the bivalves. Ectopro serpulid and sabellid worms, and like, are true suspension-feeders t use ciliated tentacles for captur and transporting food.

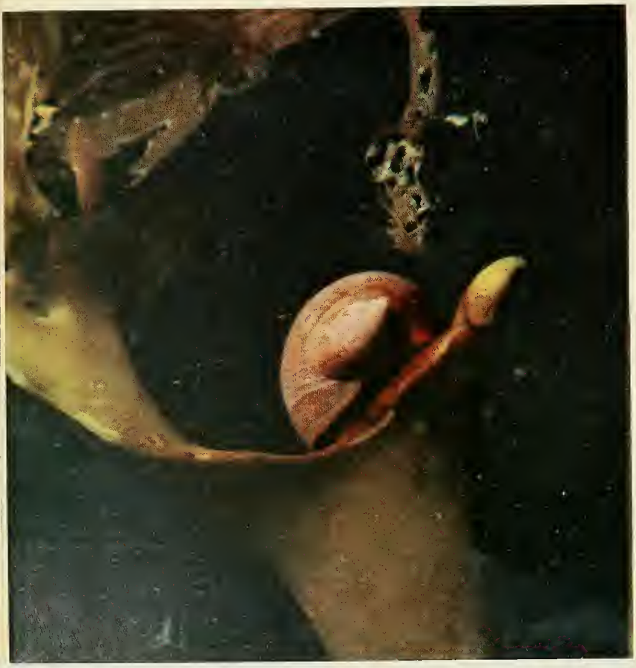
Sea cucumbers present an inter ing array of suspension- and posit-feeders. One suspension-feed type we studied on our Califor reefs is the small *Cucumaria lubr* which lives among thick stacks of fixed clam *Chama pellucida*. Fr these stacks it extends branc sticky tentacles into the free wate intercept suspended material. W its tentacles have captured eno food, they are curled back, one one, into the gullet and pulled slowly across the taut lips to sc off the food. The much larger and numerous sea cucumber *Parasti pus parvimensis*, on the other han a detritus-feeder. It is found on o horizontal surfaces near the re



BO OM-FEEDERS near reef base are typified by starfish, young Garibaldi, and sea urchins, all flesh-eaters. Sea urchins are scavengers, starfish may scavenge or feed on live mollusks, fishes eat live animals, and also scavenge.



Sheepheads and Garibaldis, Señori and Kelp Bass would often follow author around underwater, feeding debris while he collected reef anim



Smooth turban snail, *Norrissia*, feeds on seaweed, much of which has already been eaten. Few of the marine animals feed directly upon seaweeds and kelp.

se, where detritus-rich sediments cumulate. It sweeps the detritus, ith much sediment. into the mouth means of fringing tentacles. Fi- lly, a third species of sea cucumber, *ptosynapta inhaerens*, is found at e base of the reef, where it con- mes buried detritus by burrowing to rich bottom sediments.

OME crustaceans especially barna- cles and certain crabs. are sus- nsion-feeders. Lacking cilia, they e special appendages to create cur- nts. and highly fringed mouth parts trap and pass food particles to the outh. Sponges. too. are suspension- eders that lack cilia. Although they ay attain relatively large propor- ns (one species we saw was five et long) they feed essentially like otozoans—taking minute food par- les directly into cells for digestion d transport. The unique cells of the onge that perform this function are lled collar cells, because their free ds have a delicate truncate funnel protoplasm that surrounds the base a whiplike flagellum. These collar lls line the many chambers charac- ristic of the construction of larger onges. The continual beating of the gella propels water through the onge's porous walls. When food par- les borne by these currents touch e collar, they are caught and carried wn to the cell body. where they are gulfed with a drop of water to form liquid sphere called a food vacuole. gestion occurs in the vacuole while circulates toward the fixed base of e cell. At this point some digested od passes through the cell membrane amoeba-like cells that carry it to ose cells that presumably cannot d for themselves.

Coelenterate animals of the reef ow diverse feeding methods. Ane- ones are usually carnivores or scav- gers. although a very few may be spension-feeders. The same is true the innocuous-looking little hy- oids. some of which have rapacious petites and can extend the mouth ound bits of animal debris up to ten nes their diameter. Gorgonian cor- s seem to be suspension-feeders. as e many stony corals. Some stony rals of temperate waters. however, n scavenge animal debris. as can be monstrated easily in an aquarium.

We have now seen some ways in ich the giant machine, as we called r epifaunal complex earlier, withdraws continuously an impressive amount of fuel—organic matter—from the water and from detrital films. In turn, carnivores of both epifauna and infauna—including the fishes that exist wholly upon food taken from the bottom—find a rich food source among the suspension- and deposit-feeders we have described, and among the scavengers and herbivores as well. The commoner carnivorous invertebrates include such annelid worms as eunicids and glycerids, the nemertean or ribbon worms, many gastropod mollusks, and the starfishes. The most abundant of the latter on our deepest reef (Reef 500) is the opalescent starfish *Pisaster giganteus*. This is a strict carnivore whose food range includes several types of gastropod and pelecypod mollusks. On Reef 500, however, we have found that it feeds almost exclusively upon the fixed clam *Chama pellucida*. Attracted by this close relationship between *Chama* and *Pisaster*, we saw the possibility of obtaining some crude quantitative data on the productivity of this reef.

THE concept of productivity and its ecological importance may be explained thus: if we determine the number of *Chama* that exist on a reef and multiply this total by the average weight, we obtain a product that represents the standing crop, or biomass, of this species. This figure, of course, gives us no conception of how much of this organic material is produced in a given time. Such a time rate would give us the measure of secondary productivity that the investigator interested in the dynamics of ecology seeks. An accurate figure for *Chama* production rate on our reef could be got only by determining growth rate, life span, percentage of predation, and the like. But in this predator-prey relationship between *Pisaster* and *Chama* we saw an opportunity to take a shortcut to a datum that would give at least the productivity of *Chama* within an order of magnitude.

First, we found—by analyzing many measured samples—that the average number of *Chama* per square meter on the surface of the rock reef was 460. After determining average individual weight (and knowing that there were about 1,200 square meters on the reef), we could calculate that total *Chama* population of the reef would approximate 552,000, and that this total would weigh about 15 tons, of which 11 tons would be shell, and 4 tons wet weight of flesh. It was obvious that this mass represented an accumulation of several years. Exactly how many years this process required, however, is anyone's guess.

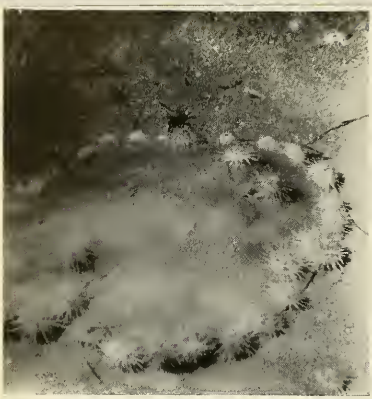
Next, we determined the number of *Pisaster* on the reef by a series of direct counts, and found it to be stable at 500, or about one starfish for each 1,100 *Chama* of all sizes. We then collected representative starfish and clams and placed them in laboratory aquariums. Over several periods, each two weeks long, the starfish were allowed to feed freely upon weighed clams. It was found that the average *Pisaster* ate 0.6 *Chama* of various sizes per day, or about 220 per year. This meant that the reef's 500 starfish would consume a calculated 110,000 clams a year, or about 20 per cent of the estimated total *Chama* population.

Having computed that there are 4 tons of *Chama* flesh on this reef, and considering the population stable, it follows that the clams *must* produce each year at least the amount of flesh eaten by starfish. Thus, productivity of *Chama* on the reef has a minimal estimated value of 20 per cent of 4 tons—or 1,600 pounds yearly.

This figure allowed us to estimate the amount of organic matter (largely plankton) that the *Chama* population eats in a year in order to maintain itself against the depredations of this one species of starfish. Assuming that *Chama* is as much as 25 per cent efficient in converting food to flesh, the species must consume more than 3 tons of plankton yearly on this small reef (figure, p. 49).

QUITE likely the *Chama* could get along without the starfish that preys on it and without the other species that inhabit its stratifications, but the reverse is surely not true. It is thus of interest to speculate upon why *Chama* reaches its maximal densities upon the upper part of Reef 500. Aside from the nature of the substratum, the two physical factors that seem to exert the greatest control on these growth characteristics of *Chama* are water movement (as wave surge) and water temperature.

The force of wave turbulence varies markedly on Reef 500: it is greatest near the top, moderates sharply as one descends along the side, and is virtually non-existent in the zone of quiet water a meter or two above the



Sea urchins form circle around dead guitarfish as they approach to feed.

sea bottom. At several points high on the siltstone reef, we have observed *Chama* stratifications of more than 4,000 individuals per square meter; near the bottom, the *Chama* density may drop to zero. Evidently, such dense stratifications can persist only where turbulence is sufficient to flush water, carrying food and oxygen, through the stacks' interstices. But, as noted earlier, this water movement must not be too severe, for in such places *Chama* is either absent or present only in reduced numbers.

Temperature may have both direct and indirect effects in controlling the major distribution of *Chama* and development of stratifications. The direct effect would control the growth rate needed to develop and maintain these dense populations. The indirect effect is found in the role temperature plays in determining the relative amounts of plankton to which *Chama* will be exposed in the course of a year. Both direct and indirect effects are related to the thermocline—a zone of rapid temperature change related to a change in depth. To qualify as a thermocline, the temperature gradient must change at least one degree centigrade for each meter change in depth. In the area of Reef 500, the seasonal thermocline prevails during the five or six warmer months, when it hovers between depths of eleven and fourteen meters, with significantly warmer water between the surface and the thermocline than below. Plankton populations often reach peak densities when the thermocline prevails. Since there is little mixing of water across the thermocline, for many days we may observe murky, plankton-filled water above the thermocline and fairly clear, plankton-free water below. It is probably more than coincidence that *Chama* on Reef 500 reaches peak densities above the zone of the thermocline.

On balance, we tend to conclude that water movement—specifically, the degree of turbulence—is the prime cause of the marked changes in frequency distribution observed for many organisms on our reefs. This could explain, for example, why we find the best development of zonation on large reefs oriented at right angles to submarine wave movements. This offers the most resistance to wave forces and provides the most turbulent waters at the top. It would also account for our observation that small reefs and those with axes parallel to wave movement tend to have a very wide life zone of the sort that appears as a response to more uniform turbulence from the reef's top to bottom. This view leads us to anticipate that deep reefs—where turbulence is minimal, regardless of orientation—may show less zonal differentiation.

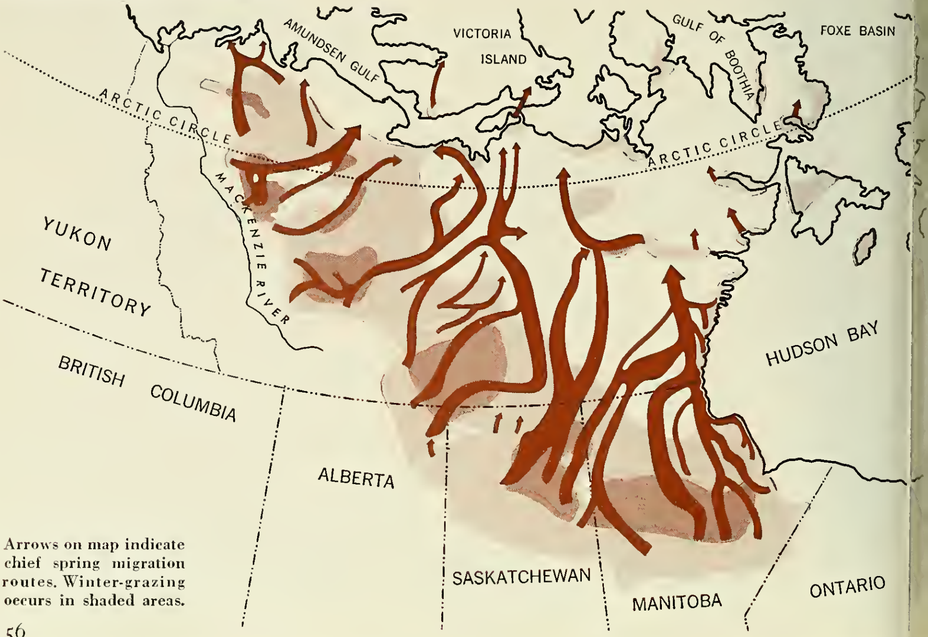
Both the turbulence and temperature can account also for the fact that we see a general reduction gradient in numbers of species and individuals as we descend. Moreover, it is a reason to expect the number of filter-feeders to drop as we descend along the side of the reef, while the proportion of detritus-feeders and scavengers will rise. The commoner scavengers of these reefs are sea urchins, large serpent starfish, and certain hermit crabs, all confined to the two deepest zones. There they find a rich supply of debris that falls from upper parts of the reef under the influence of turbulence.

This completes the broad outline of the marine ecosystem of which our reefs are an integral part. Perhaps now we can understand better why epifaunal animals can exist under such crowded conditions. Their basic form is the first consideration. There are, as we have seen, both attached (sessile) and mobile species in the epifauna. Some of these sessile species form incrustations that in turn provide secondary substrata on which other sessile species live, and in the interstices of which many mobile species find a haven. Next, we have seen that abundant food is produced by the phytoplankton as it transforms inorganic compounds into organic foods under the influence of radiant energy. This function, involving eventually the movement of energy from the
lagic matrix to the benthic, provi
a more than ample food supply
suspension-feeders of the epifau
Then again, as we have seen, not
food chains are simply unidirectio
There are, in electronic terms, f
backs in the chains, such as obser
in the formation of detritus in
benthic matrix, in which food m
rials are used and reused until m
of the matter and energy of biol
cal value is exhausted. The dep
feeders depend largely upon t
feedbacks. Finally, such tremend
population densities can exist
because of the diverse feeding m
exhibited by epifaunal animals—a
versity that allows unrelated spe
to live side by side without inte
competition for food. Furtherm
we must not overlook the signifi
fact that reproductive habits of m
epifaunal species permit the yo
to be sent up into the plankton
the pelagic matrix, where they do
compete for food with their pare

Looking to the future, our obse
tions seem to lead to the con
sion that the great limiting facto
the future development of epifa
populations is the relatively s
amount of substratum available.
haps this can be dismissed as an
demic consideration, for the n
immediate problem is simply on
survival in the face of man's activi
We are now aware of the delicate
of interdependencies that exists
tween and among components of
pelagic matrix and the benthic i
limited area. It is reasonable to
pose that such concepts can be
panded to encompass the world se
a gigantic ecosystem. If we can ac
this, then no one part is comple
isolated from any other part.
concept should caution man to
careful thought to his treatmen
the sea, once thought invulner
particularly with regard to waste
several types that he persists in
charging into it in increasing amo
At some unpredictable concentra
level, these accumulated wastes m
trigger a chain of ecological ev
that would produce very widesp
biological and geographical eff

Sculpin, normally found near
or on bottom, is venomous relativ
the rockfishes. Spines contain po

ON SPRING MIGRATION, barren-ground caribou, *above*, file over frozen lake.


AMUNDSEN GULF
VICTORIA
ISLAND
GULF OF BOOTHIA
FOXE BASIN
ARCTIC CIRCLE
ARCTIC CIRCLE
MACKENZIE RIVER
YUKON
TERRITORY
BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
HUDSON BAY

Arrows on map indicate chief spring migration routes. Winter-grazing occurs in shaded areas.

Migrating Caribou

Barren-ground herds face a serious threat to survival

By A. W. F. Banfield

A RELICT SPECIES from the Ice Age is waging what may be a losing tle for survival against the ad- e of modern civilization in the north. That species is the barren- und caribou *(Rangifer tarandus icus)* of northern Canada, closely ed to the reindeer *(Rangifer tar- us)* of northern Europe. The first bou reached North America per- 75,000 years ago, crossing a land ge over the Bering Strait that separates Alaska and Siberia. arrived some time before the continental glacial advance— aps not very long before the first an followed the same route.

The reindeer was a characteristic mammal of the cooler phases of the Pleistocene, associated with a tundra and taiga vegetation on the edges of advancing or receding glaciers.

In a similar way, the caribou adapted to Arctic and subarctic America. Here it served as the cornerstone of the comparatively Stone Age cultures of two distinct nations—the Eskimos and Chipewyan Indians. The latter group were known as the caribou eaters, and were almost totally dependent upon the animals for such basic necessities as food, hide clothing, tool handles, sinews for sewing, and oil for lamps. The Eskimos were generally less dependent upon the animal, basing their economy more upon the marine mammals—seals, walrus, and lesser whales—although they turned to the caribou for such important items as winter clothing.

The North American Eskimos and Indians relied upon a primitive hunting culture. They speared the migrating caribou herds from canoes and kayaks. They captured them at water crossings or in pounds made of spruce tree fences (or columns of stones on the tundra). They sometimes stalked with bow and arrow, the hunters often disguised in caribou hides and antlers. Such methods were

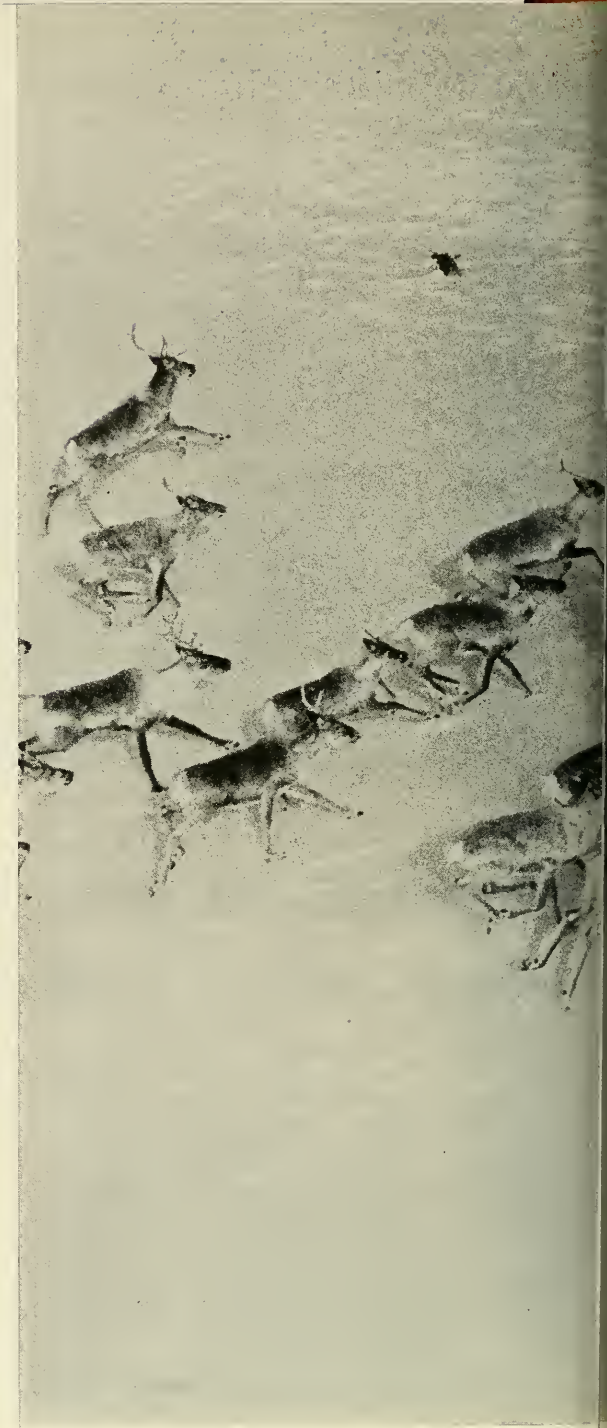
Dr. Banfield, now Chief Zoologist of the National Museum of Canada, took part in the Canadian Wildlife Service's study designed to survey and conserve barren-ground caribou.

probably not unlike those of our Stone Age ancestors, and could still be observed in certain parts of northern Canada until about 1950.

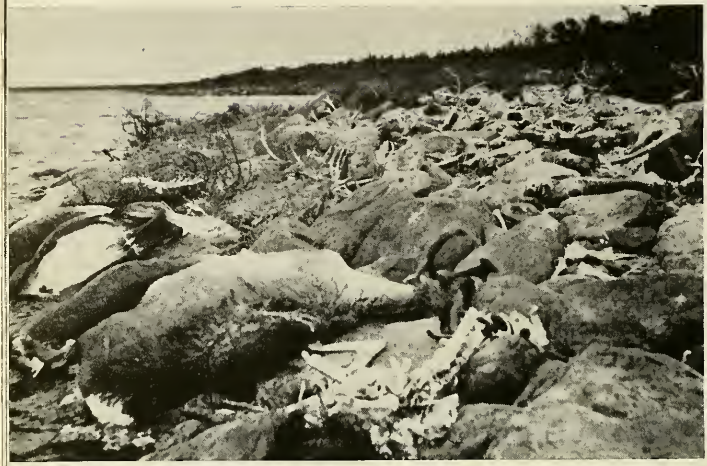
These, then, were the sights that greeted the first European explorers to the northland: great herds of caribou roamed the Arctic tundra in countless numbers, comparable to the huffalo herds of the prairies, followed by nomadic bands of Indians and Eskimos. However, the advent of Europeans upset the centuries-old balance between caribou herds and their human predators. The fur trade led to long winter trips to trap the fur bearers that had been taken only incidentally before. Larger dog teams were needed, as were large caches of caribou meat to feed the trappers and their dogs on the trail. With these changes were introduced the tools necessary to facilitate the killing of caribou—the white man's firearms.

The remoteness of the caribou's range, together with the sparse and primitive human population, hindered a really accurate appraisal of the animal population. Exaggerated estimates ran as high as 100 million. The famed naturalist Ernest Thompson Seton estimated the caribou herd at 30 million in 1907. As late as 1938, the caribou population was estimated to be as high as 2½ million animals.

With the increased postwar tempo of development in Canada's Arctic and subarctic regions, fears for the fate of this important natural resource were expressed. Federal and provincial authorities recognized the urgent need for an intensive investigation and undertook a co-operative preliminary survey in 1948 and 1949. Previous attempts at estimating the caribou population had been handicapped because of the slowness of the traditional northern transportation methods of dog team and canoe. However, pioneer aerial searches for lost bush pilots in the Canadian Arctic during 1937 and 1938 led to the de-



In wild flight, prompted by airplane, caribou band scampers with surprising swiftness across snow-covered wastes.



Uncontrolled hunting by Indians, who spear caribou from canoes, results in carnage, *above*. Each year, thousands of carcasses are thus abandoned and rot.

velopment of the aerial caribou survey technique. During spring migration the herds travel in closely packed columns. They tend to follow frozen lakes and rivers. On sunny afternoons they bed down on the snow-covered lakes and are easily photographed and counted from the air.

The preliminary aerial survey in 1948 and 1949 indicated an estimated population of about 670,000 animals between Hudson Bay and the Mackenzie River. The annual crop of calves was estimated as 145,000. The number killed every year by hunters, based upon hunting returns, was about 100,000. Wolf predation, diseases, accidents, and severe weather caused losses that appeared to exceed the annual increase and to result in a declining population. Many other factors—loss of winter range from forest fires, blizzards at calving time, crusted snow—were thought to cause catastrophic losses at certain times and places.

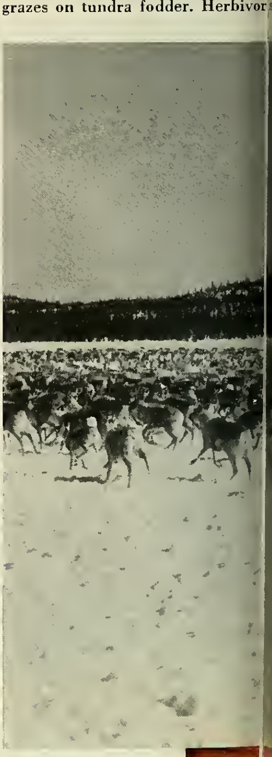
A resurvey was undertaken during the winter of 1955-56 with alarming results. On the basis of the same aerial survey technique, the population was estimated to have dwindled to about 275,000 animals. Although some drop in the population had been anticipated, as a result of the preliminary survey, the actual decline exceeded the expected by about 50 per cent.

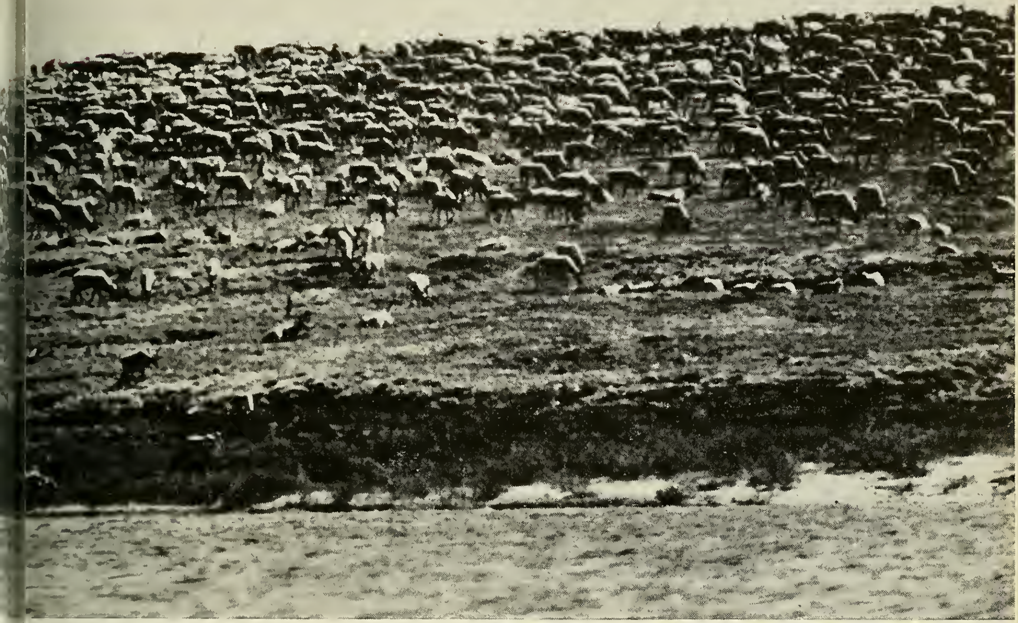
Steps were taken in 1957 and 1958 to rectify the situation. Teams of specialists from the Federal Department of Northern Affairs and Indian Resources, the Federal Indian Affairs Branch, and the Provincial Game Branches of Alberta, Saskatchewan, and Manitoba co-operated in an intensive investigation into the basic causes of the caribou decline. The prevailing needless hunting waste of caribou by Eskimos and Indians was recognized, and vigorous educational steps were taken along sound conservation lines by means of cartooned pamphlets, film strips, posters, and courses in the schools. The hunting laws were tightened, bag limits for natives and resident Europeans were reduced, non-resident sport hunting was eliminated, and cows and calves were protected in spring. Ultimately, district quotas may be set. Auxiliary food supplies of whale, walrus, and bison meat were utilized to replace caribou, and storage facilities were established in some settlements.

Finally, a vigorous wolf control program by paid government hunters was undertaken for the first time over a huge area of subarctic Canada, resulting in a significant drop in the number of wolves. During control operations over a five-year period, about 4,000 wolves were taken—about half the estimated population.

Although all scientific reports have not yet appeared from the most re-

On summer grounds, the herd, *ab* grazes on tundra fodder. Herbivor





animals, the caribou feed principally on lichens and some small tree growth.

ON NORTHWARD TREK, this herd, *below*, is sent scurrying by approach of man.

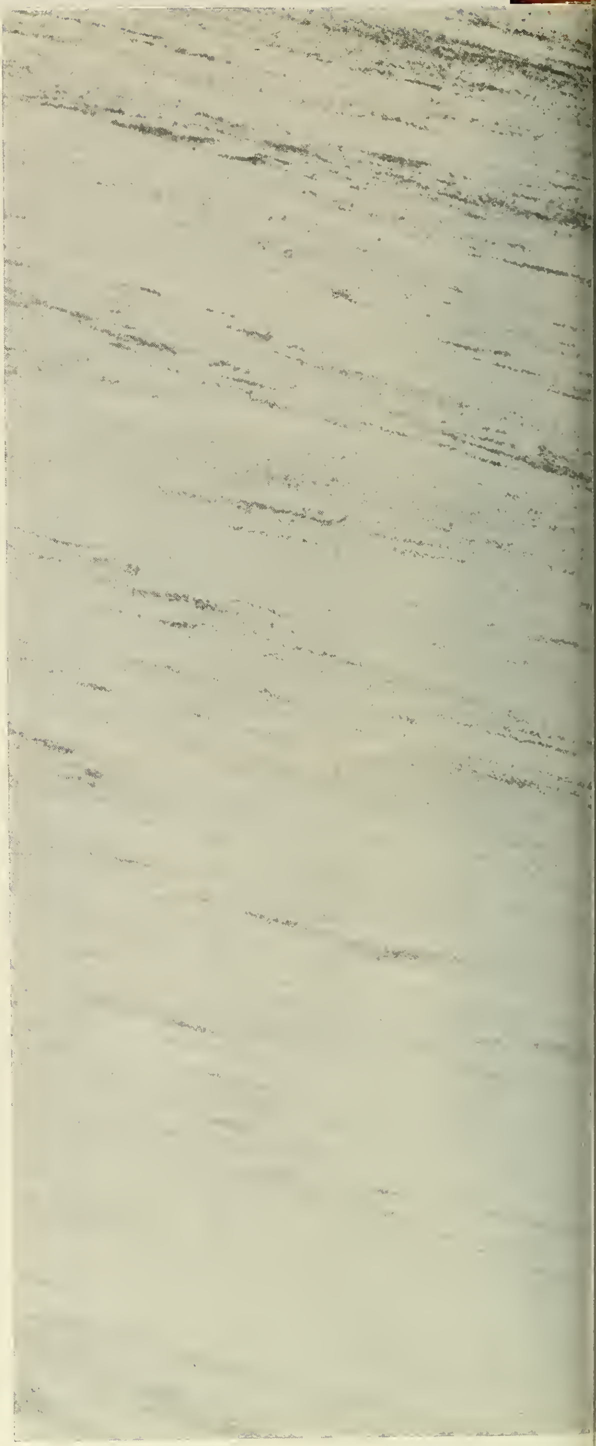
Migrating caribou average 19 miles a day, and some travel over 800 miles.

Skeleton of fawn, *above,* witnesses the toll taken by elements and wolves.

cent co-operative research project, it is known that significant advances have been made in our knowledge of the role of snow in the caribou's food habits and the effect of "windchill" on newborns. In addition, new information on caribou migration was obtained by biologists in light aircraft "leapfrogging" after the migrants from the winter range to the summer range 800 miles away.

Pressure has been taken off the caribou in still another way as new economic possibilities have been opened to the Eskimos. Work in mining and military establishments, in social services, and in aerial transportation has reduced the need for caribou as the main source of sustenance. This change came at a fortuitous moment, for the disappearance of the herds resulted in starvation in some very remote Eskimo camps in Keewatin District, and caused grave hardships over a much larger area in northern Canada.

There are some who say that northern development has doomed the caribou in any case, and that we should not concern ourselves with its fate. But the stunted subarctic forests and tundra pastures underlaid with permanent ice are of little use for modern forestry or for agriculture. The caribou is the animal best adapted by nature to utilize these habitats. It is suitable for an extensive type of herd husbandry, and if properly managed could continue to provide bounty "on the hoof" to northern residents remote from supplies of domestic beef.



On trail of caribou, a wolf streaks across snow, *right.* But a worse threat to caribou's survival is human hunter.

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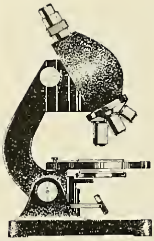


NATURE and th MICROSCOPE

Varieties of Instruments

By Julian D. Corrington

Thus far in our explanations we have achieved simple definitions of magnification and microscope: any view of an object closer than the ten-inch near point is a magnified one, and any appliance that can provide such a view is thereby technically a microscope. A drop of water hanging in a wire loop, spectacle lenses, and the pinhole card were cited as examples of devices that fit this definition but are not ordinarily called microscopes—by common usage we restrict this term to an instrument consisting of one or more lenses, held in frames or tubes for manipulation.

When microscopes were first invented, the interest in them centered around the fact that one could see finer details in an object, or see things never before known. Pioneer workers looked at anything and everything, initiating a great curiosity in the construction of all material objects. But it soon became evident that early microscopes had their limitations, a recognition that led to improvements in existing equipment and to the invention of various specialized instruments for particular purposes. Today, this specialization has gone so far that the number of diversified types of optical instruments is almost legion: whenever a new need arises, the manufacturers have responded by developing a suitable magnifier, and this month we will describe and classify the principal kinds.

The earliest magnifying instruments were all *simple* microscopes, after the fashion of the *hand magnifier* in use today. Commonly, a single biconvex lens is mounted in a tube or frame with a handle, and is held close to the object on one side and to the eye on the other. An enlarged image is provided, but, as shall be explained later in this series, such images are subject to a number of defects, overcome for the most part by combining two or three lenses to work together. When two lenses of different composition and shape are cemented together, the magnifier is termed a *doublet*: when three, it is a *triplet* or *triple aplanat*—the finest and also the most expensive of hand lenses. The entomologist and the botanist use this kind of aid. Magnifications most frequently seen are 5X, 10X, 15X, and 20X, with the most desirable strength for an purpose magnifier.

Even with instruments of this c there are specialized designs. *reader* has a large diameter, 2X or magnification, and a long handle, an made to assist the elderly or per with weak vision who wish to read c nary type; the collector who scans p age stamps, coins, small insects, and like: the etcher or engraver; or th who inspect the fine detail of maps photographs. The *fingerprint reade* equipped with engraved scales or ings, which mark off measured ar The geologist uses a reader with o sorts of scales to count soil particle

The *linen tester* folds flat in pocket. When opened it provid fixed focus covering exactly one squ inch of field. Its original purpose wa help the textile buyer count the nun of threads per inch in woven goods, it has many other uses. The *loupe* is l in by the eye socket bones, leaving l hands free: it is employed by the eler who inspects the works of y watch or gemstone settings in rings

When mounted in a frame on an equipped with a focusing gear, a mented with a substage and mi spring clips and base, the magnifier comes a *dissecting microscope.* I hands can then work with the specin

The *compound microscope* has sets of lenses. One is close to the ject to be examined and hence is ca the *objective;* the other, some dista above the first and close to the ey the observer, is called the *eyepiec ocular*. Such an instrument prov magnifications to a maximum of 2.0

Strangely enough, there has n been a universally adopted name for ordinary compound microscope. It been termed the *laboratory microsc* although this is obviously a poor de nation, since almost all microscopes intended for use in laboratories of kind or another. It has also been ca the *biological microscope*, but a la proportion of them are employed non-biological work. So we shall hav settle for the ambiguous name c *und microscope* and indicate all of t many offspring of this original in- ument by their specialized monikers. yone who has pursued the beginning logical course in high school or col- e will be familiar with the appear- e of this basic type, equipped with objectives—low and high power— a single tube with one eyepiece. ual magnification is 100X or 430X. f we add a third objective—an oil nersion one, to obtain the highest gnification (970X) and resolution— must then also have a substage con- iser to supply adequate illumination this additional part. This gives us an anced model, the *research micro- pe*, considerably more costly, and able of revealing much finer detail in image than may be obtained with ulation instruments. There are many borations and variants of this theme. e addition of a mechanical stage, by ans of which the whole field may be nned systematically, yields a *medi- microscope*. This type is essential in od-cell counts and bacteriological rk, and is so named because these ra trappings furnish the minimum re- rements specified by medical schools preclinical work.

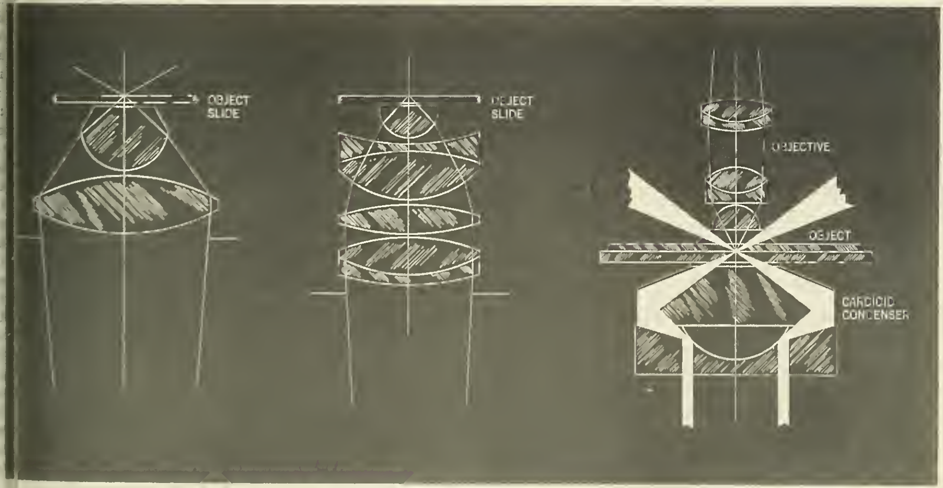
radical innovation was the *binocu- lar microscope*, which did away with ward and unnatural use of one eye. image, from the single objective, is it and then redirected by systems of sms so that the observer sees it in two pieces in which the tubes are either allel or convergent. All research and lical types of microscopes may be purchased with either monocular or binocular stands, and many makes have interchangeable bodies—the binocular for visual observation, the monocular for photomicrography.

DR. CORRINGTON's column appeared regularly in NATURE Magazine for nearly twenty years, and can now be followed in the combined magazines.

An entirely different sort of instrument is the wide-field *binocular, stereoscopic microscope*, or *3-D* (three-dimensional) *microscope*. This type employs paired eyepieces, tubes, and objectives, and is in fact two microscopes, side by side. Two images are produced, one from each objective and one for each eye, and these are fused in the brain into a single image, just as are the two retinal images from our two eyes in ordinary vision. There must be a spatial adjustment for the paired eyepieces to give the proper interpupillary distance, which varies from person to person. When correctly set, a sharp fusion image with considerable depth is provided. Only lower powers of magnification are possible, from 2X to 40X, with 10X or 20X generally preferred. Bausch and Lomb have recently introduced their "power pod" for this type of microscope. It houses a *zoom lens* assembly, by means of which a continuous change from low to high power, or the reverse, yields an image that remains in focus throughout the shift. The object appears to zoom up toward the observer, becoming larger all the while.

The 3-D microscope is a partner rather than a competitor of the ordinary compound instrument, as the two kinds are usually employed with different classes of objects. The 3-D is preferred for whole objects, such as a small animal (planarian), embryos, parasites, insects, small fruits, seeds, small skulls, and for examining sections of a whole organ (a kidney, for example).

In regulation procedures the illuminated circle that is visible—the *field* of the microscope—is always brighter than any object. Therefore, this method of observation is termed *bright-field microscopy*, a designation made necessary by the discovery of an alternate and opposite effect, *dark-field microscopy*. In dark-field work, an *annulus*, or circular *stop*, is placed below the condenser. This has a black metal center that cuts off all direct light from the mirror. Rays that pass through the outer annulus, or open circle beyond this central stop, are so oblique that, having traversed the object on the slide, they proceed onward at such an angle that they do not enter the objective lens at all. Therefore, when the observer looks down the eyepiece, he does not see these rays and the field appears perfectly black. Meanwhile, particles in the object have intercepted some light rays and refracted these up through the tube so that they become visible to the eye. Each such intercepting particle becomes a new source of light, a phenomenon named *Huygen's Principle*, after its discoverer, a seventeenth-century Dutch physicist. The particles seem to glow as if self-luminous. A paramecium will scintillate,



MENTS of compound microscope, *left*, are designed to gather siderable light for general visual observation. In research roscope, *center*, a substage condenser directs a light beam of the desired numerical aperture. Of special use on transparent material is dark-field condenser, *right*, which produces cone of light that penetrates specimen, making field appear to be dark.

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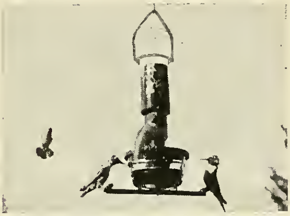

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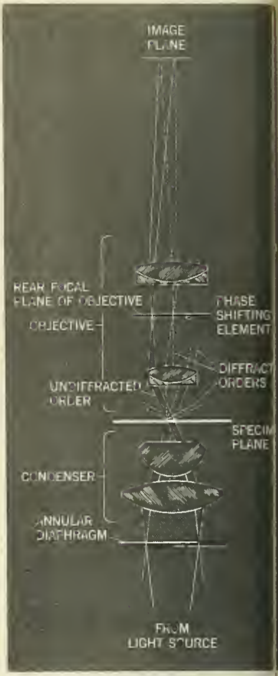
as if inwardly illuminated as it swims about in an inky-black field. This method reveals a great deal of information as to the surface markings, and has proved a valuable supplement to bright-field microscopy. Any microscope equipped with a condenser may be used for dark-field study either by adding a dark-field stop or by substituting a special form of condenser.

In geology and chemistry another principle concerned with visible light has long been in use. Colorless light, such as that from the sun, vibrates in all directions around its axis of forward propagation, but certain substances—such as a calcite crystal or the synthetic material Polaroid—can split the light into two rays. One, the extraordinary ray, is refracted out of the picture; the other, the ordinary ray, is *polarized*, the vibrations being restricted to a single plane. If we place a circle of Polaroid film below the condenser, the only light that gets through is polarized: hence, this film is called the *polarizer*. This light still looks as usual to the observer—he cannot see that any change has been effected. If another such film (called the *analyzer*) is now placed upon the eyepiece, a number of consequences are possible. If the planes of polarization of both films coincide, the light coming through seems like ordinary light, and no visible difference is observable in the microscopical image. The *optical slots* of the two Polaroid films are parallel. As the analyzer is rotated, however, its optical slots finally are at right angles to those of the polarizer. Light is then extinguished, and the field is black.

When an object is illuminated by polarized light rays from below, one of two things happens. If the object belongs to a class of substances termed *optically active*, it will repolarize the light and transmit such altered rays to the eyepiece. The amount of repolarization depends on the nature of the material. If the object is *optically inactive*, it will not repolarize the light, and, as a result, will show no effects.

When working with an optically active substance, there comes a point, as the analyzer is rotated, at which the optical slots are crossed at right angles and the field appears black. This place may be recorded on a scale of angular measurement, and thus the *angle of extinction* determined. Inasmuch as this angle differs for each different crystal system, an identification of the type of system being observed may readily be made. This is a great aid in solving unknowns of optical mineralogy and chemistry. Between white light and extinction, gorgeous color effects are observed, and these have been preserved in the form of spectacular colored movies of crystallization, especially in the case of organic acids. In biology, too, cer substances—notably keratin (hor are optically active and the polari microscope is an aid for identificatio these materials however they occur.



Phase contrast allows observer to transparent objects. Principle invo formation of final image by interfer effects of portions of two light be

Until quite recently, all microsc used light to produce an image no prefix to the word *microscope* required. But the twentieth century the discovery of other sorts of en that could be used to form images example, the electron microscope. the phrase *light microscopes* came being for regulation instruments. W then, are not light microscopes?

Physicists know that visible lig only one small portion of an enor band of radiant energy. When a so of energy—such as the sun, a cand hot stove, a radio transmitter o X-ray tube—is emitting energy, the ticular type of emission depends or quency of vibration and the resu wave length. Long waves, like those erated by shaking a rope up and d have a low frequency (number of v tions per second), and the wave le are measured in meters. When the

b· of vibrations per second is stepped
u, the wave lengths become shorter:
s l more vibrations, and we get into the
alm of heat and infrared light, invis-
ie to the human eye but capable of
reption by other means.

n the first half of this century it was
dcovered that organs are located in
t heads of the pit vipers (including
herican species of moccasins and rat-
tsnakes) which are sensitive to emana-
tns of energy at the infrared level.
Tis is a remarkable adaptation that en-
ales these snakes to strike at warm-
bnded prey at night. Man has no organ
tt can register rays of this frequency,
b his cameras can, and infrared aerial
ptographs of cities may be made even
anight or through layers of clouds.

'isible light comes next, occupying
b a single octave of the whole electro-
mgnetic spectrum. Above this comes
uraviolet light, again not detectable by
hman vision, but capable of being seen
b certain other animals. Cameras
eipped with the proper optics and film
my reproduce subjects illuminated by
uraviolet, so pictures taken through a
mroscope furnished with ultraviolet
oics—quartz lenses—may register de-
ts that are too fine for recognition by
lses used in visual work. Successively
hher in the spectrum are soft and hard
Xays, electron beams, and, finally, cos-
m rays, which come to us from outer
sce at an enormous frequency and
eremely short wave lengths.

'oday, we have ultraviolet micro-
scpes, X-ray microscopes, and electron
mroscopes, used by specialists in bio-
lcical research, medicine, and industry.
A easily understood analogy compares
th performances of these various in-
stments with various sizes of mesh in
fi nets. In using a light microscope,
th wave lengths can be compared to a
vy coarse net, adapted to catch only
sh large creatures as sharks: all
ıller fishes get through and are not
cght. In succession, the other forms of
ergy compare to meshes continuously
fir, the electron waves, finally, being
li mesh that entangles minnows. Ac-
cdingly, detail so fine that it escapes
obervation in the light microscope will
bintercepted and revealed by the elec-
t apparatus. This depends on the
olution or *resolving power* of a mag-
n ing instrument—its ability to render
deil. The shorter the wave length of
ergy used, the finer the detail that is
te seen. Resolution and magnification
a the two essentials of microscope ob-
jcive; of the two, resolution is consid-
d the more important.

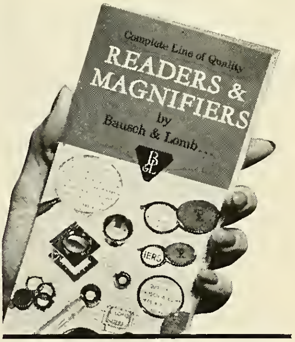
MEANWHILE, the light microscope has
recently been the source of a
s tling discovery—the *phase-contrast*
p *ciple*. To understand this newest
a most important development in light
microscopy of the past hundred years, we must digress to explain the difference between transparency and contrast in the specimen.

In the routine procedure of microtechnique—the preparation of material for examination under the microscope—the subject must, at some stage, be rendered as transparent as possible in order to transmit the light coming from the mirror below the stage. Thick or darkly pigmented objects will not pass enough light through to make them visible; they are more or less opaque and hence useless for observation save by incident illumination. Hence, thin sections of tissues and organs are cut on a microtome—a refined, laboratory example of the butcher's meat slicer—and mounted on slides. Along with other steps, they are treated with xylene to confer transparency, but this can defeat the very purposes of the technique. The specimen can be made so transparent that no detail at all can be seen.

TRY this simple experiment. Place some colorless glass beads (or broken bits of glass) in a test tube or small glass container of benzene. Then, try to find the beads. You will not be able to do so, because the fluid and the glass have the same *refractive index;* that is, they bend the entering light rays to the same degree, and the emergent rays all appear the same, with no distinction between what is benzene and what is glass. But now place some colored glass beads in the same reagent: they may be discerned perfectly. If the beads are red, for example, the red dye in the glass absorbs light rays of the green-blue-violet end of the visible spectrum, refracts those of the red end to our eye, and thus appears red. The benzene does not do this, and so the factor of *contrast* is provided. The beads are still *transparent*, but are rendered distinct through contrast with the surround. The same applies to tissues: we stain them with biological dyes for contrast and then put them through xylene, in the process called clearing, to yield transparency.

In phase-contrast microscopy only unstained material is used, but the entering light is altered so that the background illumination is seen by wave lengths of ordinary light that are out of step with those passing through the specimen. An annulus is placed below the condenser and another one, called the phase plate, is situated in or above the objective lenses. Either or both of these rings may be so treated as to retard or advance the phase of the wave lengths of transmitted light. This provides contrast between the object and background without interfering with the transparency of either.

Waves are undulating, with crests and troughs. If the background light waves



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arrive at the focal plane of the instrument at their crests, and the waves refracted or diffracted by the specimen also arrive at their crests, there is reinforcement, and light seen by the observer is bright. If one set of waves arrives in crest and the other in trough, there is extinction, one set canceling the other. But if, by means of the phase-shifting annuli, one set arrives out of phase by one-quarter of a wave length, object and background exhibit contrast, but without loss of transparency.

The effect is similar to that of staining, but no dyes are used. Indeed, the process has been referred to as "optical staining." Living cells, such as amoeba or paramecium, are viewed in their natural movements, and are seen with great clarity of detail, impossible by any other method. For instance, in the biological laboratory it has been customary to have the student first observe living paramecia for behavior. He is then given fixed and stained slides of the dead animals to study—for such structural detail as nuclei. When the microscope has phase-contrast attachments on it, the nuclei show in the living protozoans as well as if they were stained, yet the animal, all unaware of this concentrated human interest in its affairs, goes about its daily business of living.

A COMPLETELY different set of applications is introduced by the *comparison microscope*. Here there are two objectives, several inches apart, scanning two different fields of view, but with a single eyepiece. The two tubes are capped by prisms that direct the two separate images into a single field of view, divided by a hairline in the center. The observer sees the image from the left-hand objective displayed in the left half of the eyepiece field while, across the hairline, the image from the right-hand objective is seen. Manifold uses in chemistry, industry, and especially in scientific crime detection are made possible with this microscope. In one form, the colorimeter, a dye or paint of known saturation is held by a tube below the right-hand objective; an unknown—to be tested, compared, or matched—is in the left-hand tube. By focusing, the two colors may be seen side by side in a single field. A measured amount of pigment may be added to the unknown until the two colors agree precisely. The hemoglobinometer is used to match samples of blood. The unknown is adjusted until it matches the known and a direct reading is then made on a scale.

Fingerprints may be matched, or proved unlike, so exactly by means of this instrument that enlarged photomicrographs, for projection in the courtroom, are now admissible evidence in all legal proceedings for personal identification. The left half of a fingerprint is seen in the left half of the field, right half of a supposedly identical gerprint in the right field. If the prints are, in fact, from the same di all the friction ridges will match up fectly across the central hairline. If two prints do not match, it is clear t were not made by the same finger.

MANY variants of all of these ins ments are possible. The *shop croscope* may be held in the h permitting an inspector to examine castings, screw threads, and other chined work for imperfections; the *tallograph* makes photomicrograph metal alloys to analyze the blend of and carbon or nickel in steel metallu for example; the *optical pyrometer* lows an inspector to look into the ter heat of a blast furnace from a dista and read the temperature on a scale; *refractometer* gives the refractive in of translucent substances at a gla the *ophthalmoscope* is used by p cians in scanning the blood vessel the retina of your eyes; the *otoscop* designed to look into the ear. *Ama* or *miniature microscopes* are less pensive and there are smaller mo for the youngster or beginner. Som these are very good, but worthless amples are often offered for sale. T are special microscopes or access for taking either still or motion pict through the instrument, for ma drawings or measurements, or for jecting an enlarged image on a sc

While this by no means exhausts list, it will serve to give a picture o great multiplicity of magnifying in ments available today. The reader well ask, "This being the case, w microscope is the one for me?" All pends on what you want out of a m scope. It is best to buy an ordi compound type first. If and when a cialty has been decided upon, you know what additional optical aid may require. I shall be glad to a readers of this department who wis pursue the question further. Ad inquiries to me, at NATURAL HISTO

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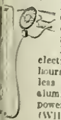

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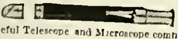

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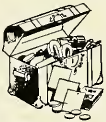

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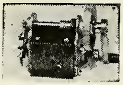

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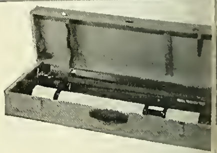

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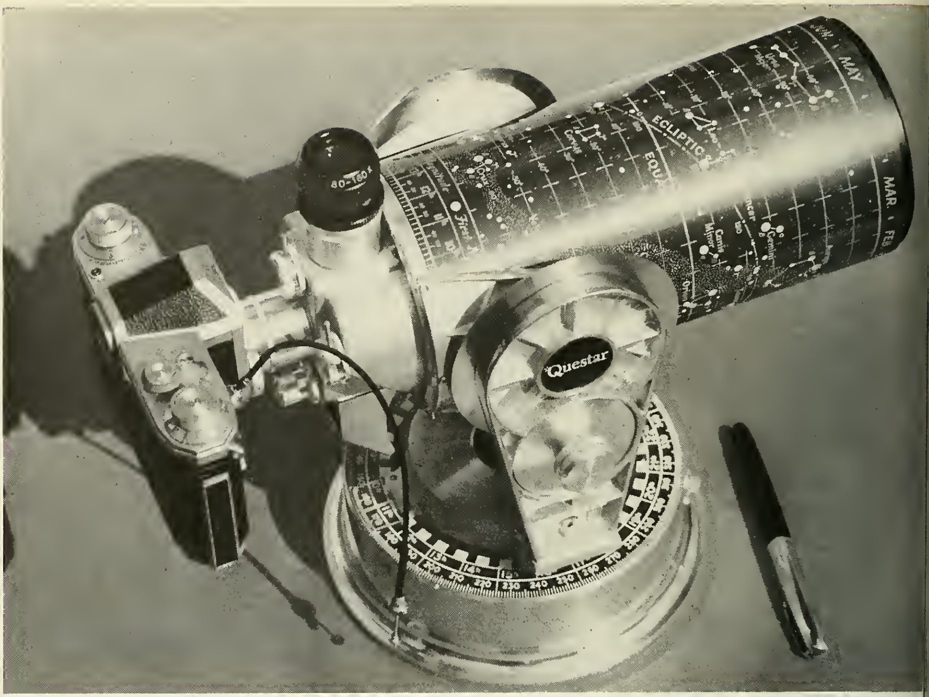

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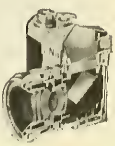

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COVER: For years, both Biblical scholars and botanists have attempte identify the many plants mentioned in the Scriptures in a search for clue the daily life of the period. The flowers in the cover's "bouquet" grew in fields of the Holy Land in Old Testament times. Clockwise from the top iris, narcissus, dandelion, saffron crocus, tulip, hyacinth, and sta Bethlehem, surrounding anemones in the center. On page 30 begins a discus of uses to which plants were put in the ancient Mediterranean area, illustr with Anne Ophelia Todd's magnificent paintings in black and white and in c

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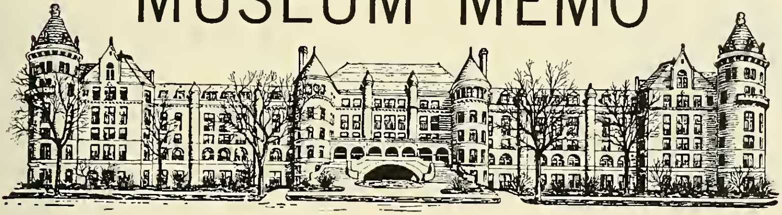
MUSEUM MEMO



BY JOHN O'REILLY

THE American Museum of Natural History has long portrayed various aspects of man. Primitive cultures have en shown through habitat groups and displays of man's ols, utensils, and art. In more recent years, there has en a tendency to delineate man's place in nature, display- g his destructive and constructive activities on the earth inhabits. Now, for the first time, the Museum has taken in apart, enlarged the delicate mechanisms that make m run and examined him as a biological phenomenon. In the new Hall of the Biology of Man, Museum techni- ins have created a series of displays that are instructive a degree never before achieved in an exhibit hall. Using w techniques and new materials, they have been able to oduce movement as well as form and color. It is a human ief that beauty is only skin deep. But nature has proved be a master designer, not only in the matter of man's ateral symmetry but also in the marvelous packaging that has arranged all man's organs and systems within skin-covered case. When these taken out of the case, greatly arged and given color, they re- d form and design that give the to that old saw. Visitors will be prised to discover that man's in- es, too, are beautiful.

he concept of this hall of human logy—as the first of a series of dealing with man—was devel- d fifteen years ago by Dr. Harry Shapiro, Chairman of the Mu- m's Department of Anthropol- . Recently we toured the exhibits Dr. Shapiro. He was fagged from handling the problems always arise in the weeks before the opening of a hall, but his enthusiasm for his pet project was trong as ever despite last minute crises.

I'd like to emphasize this," he said. "In planning this , we realized that people will come here who don't have h background in this subject. There will also be ad- ed students. We have had to plan the exhibits so they be meaningful to both groups. If you want to take the , you can learn a great deal here. It is plain, scientific, ytical, and it's got a lot of solid stuff in it."

r. Shapiro then moved about the hall, discussing each e displays. He began with a huge tile mural on which eat spiral depicts the span of evolution through two on years, from the first one-celled creatures' appear- : on up to the little sliver of time that represents the age of man. Across from this, against a mural representing the many kinds of primates, are seen the sculptured heads of fourteen types of fossil man.

The second section of the hall begins with a greatly enlarged human cell, fashioned of plastic arranged in layers that show the details of its structure. Models of different types of cells show how they are specialized to form skin, nerve, muscle, and other parts of the body. The reproductive process is explained and traced by models of the male and female reproductive systems, the formation of eggs and sperm, fertilization, embryology, and birth.

In addition to models in plastic, there are nine actual fetal specimens, tracing the embryo's growth from nine weeks to seven months. Here and there in the hall are other such specimens, including an entire digestive system and a human heart, preserved by impregnation with plastic. We were much impressed at seeing an actual human heart. But even more impressive was a plastic model of a heart in which the valves open and shut as "blood" is pumped. This and a number of other models create amazing effects through the use of plastic that transmits light from edge to edge while its surface remains unlit. If the surface is carved or etched, light appears there. By superimposing a number of etched layers, colored light produces an illusion of depth and movement. This technique is used to reproduce the circulatory and pulmonary systems, as well as for an exhibit in which an ovum leaves the ovary and travels to the uterus.

The other inner workings of man, from his digestive system to his emotions, are all treated in this magnificent hall. As a focal point, the "transparent woman," a life-size figure in clear plastic, stands before a panel of black mirrors. The mannequin turns slowly on her base, as a recorded voice describes internal structure and the plastic organs light up one after another.

As we were about to depart, another aspect of the hall became evident. The walls and columns are done in plain gray and white and the cases are aluminum: the exhibits, themselves, provide the hall's accents of color. The over-all effect is striking, and quite different from any other of the Museum's many halls. We stood there for a while, taking in the full sweep of this $450,000 masterpiece. "To me," Dr. Shapiro said at last, "it is the culmination of a dream."

Reviews

Men and their music round the worl

By Colin Turnbul

Today, many sciences are made more readily comprehensible to the layman through popular paperback accounts written by scientists themselves. But the discipline rejoicing in the ungainly name of "ethnomusicology" has not been so popularized. This is a pity, because this field of study touches every one of us, and puts a wealth of valuable and important material at our disposal.

To benefit from a knowledge of this young science, the layman does not have to be a skilled musician, for ethnomusicology is primarily a study of music in its social context. The student is not, or should not be, interested merely in the technical differences between the music of different peoples, but rather in *why* different peoples make different music, and what significance can be attributed to such differences. So the layman, if he were to learn something of this science, would not add to his total sum of knowledge alone; he might also find a new world of delight and interest. Above all, he would learn a great deal about other peoples—as well, perhaps, as his own—that might surprise him.

Even in the absence of some book called *Popular Ethnomusicology*, a start is possible, thanks to some excellent recordings that are available on the commercial market (most are accompanied by detailed explanatory texts). I shall mention here only certain records put out by three of the major American companies in the field. Necessarily, then, there will be omissions both of deserving records and of deserving companies. The former is inevitable; the latter, however, is deliberate. The companies mentioned have, to varying degrees and in varying ways, consciously dealt with the problem of issuing records that, however good and worth while, are not likely to return any appreciable sales profit. These companies do so because they realize that folk and primitive music are an essential part of man's musical heritage.

I have also enlarged the field, for the purposes of this review, to include religious music, because this is a fundamental aspect of music—as much in an African chant as it is in Mozart's *Requiem* or today, perhaps, in rock-and-roll. The border line between folk, primitive, and religious music is a tenuous one, and the division I give here is quite arbitrary. Perhaps this point is best seen in historical perspective.

Archeology tells us something of the early beginnings of music. A comparative study of still-existing "primitive" (in the non-derogatory sense of "less complex") societies, in turn, can tell us even more, for here music is often used much as it must have been from the first dawn of humanity. We have in our possession drums, whistles, and harps dating back thousands of years: from all the evidence available, we come to the conclusion that music was first and foremost a means of communication. In this context, communication involves more than jungle drums and the "bush telegraph." Certainly drums, hollowed logs of wood, trumpets, and other instruments were and still are used to communicate between one village and another over considerable distances. But music was also thought of as having the power of communion—with divine spirits or with departed ancestors.

When the Western world inherited the Greek musical tradition, it inherited two things. One was a well-established body of musical theory, based on a strong Oriental influence. This involved the belief that music was inextricably bound up with religion, which demanded the exact performance of special modes for each festival or ritual. Without the music, the ceremonies were considered ineffective. But we also inherited the seed of intellectualism planted by Plato and Aristotle, who believed that music was more than form; that it was essential to the general process of education, shaping the mind and the soul.

The philosophers included music among the mathematical sciences, by which man might understand the harmony of the universe. This germ of reason was eventually to split the course of musical development into two distinct directions. One was the development of what we call "art music." The clergy took over the intellectual development of music, as they did the practical development of its function in Christian ritual. From this body of scholars emerged a totally new, highly formalized theory of music, and the acceptance of the tempered scale with all its harmonic ramifications (this had been tried, ages l fore, by the Chinese, and rejected as n in consonance with the music of t spheres). Along with this developme there emerged new phenomena: the p- fessional composer, the professional p- former, and a purely spectator audien

At the same time, the old mainstrea continued, although now divorced fr its original religious association. This what we call folk music. It was still ma by the people, with professionals eme- ing only in the form of wandering m- strels. And its function was still the sa basic function of communication. Te minstrel was the one great means f spreading local or national news in e days, not so long ago, when the bulk f the population was not yet literate. F k music was also the means of consolic- ing and preserving traditions, of pass g on from generation to generation a gr t body of knowledge that we somew t condescendingly call "folklore." M t of this folklore has been lost and, a it was frequently disguised (sometimes - liberately) in the form of allegory. e remainder is often difficult to interp t accurately. But a great body of tr i- tional music—dating back to our n historic past and linking us in form d function with even earlier beginnin— still waits to tell us something.

Let us look at some of the record gs that are readily available. Folkways l c- ords head the list, as the only com r- cial company dealing exclusively th the field. They list some eight hun d recordings, every one of which is m n- tained permanently on issue. In addi n to their ethnic series, they have a li- gious series, one on science, one on is- torical and educational Americana, ne on literature, and others specially le- signed for children. They also ha a vast backlog, which doubtless woul be issued if their budget were a little hi er above the marginal level.

With a public that does not res nd kindly to anything that is not in st o, or at least in ultra hi-fi, Folkways ve no very easy means of doing the job ey set out to do—to preserve and pr nt authentic documentation of diff nt types of music and sound. With su a charter, gimmicks must be eschewe nd here the dangers are very real. It is nortunately, not unknown for recording ngineers to boost certain parts of a muical performance. to alter the balance leliberately to single out one instrunent. and then to put the whole bag of ricks (and that is precisely what it is) hrough an echo chamber.

The result is fascinating to listen to, ut it does not answer the criterion that 'olkways try to maintain: that the lisener should hear just about what he ould at an actual performance. given in s natural surroundings rather than in studio. This is no academic quibble. is of major importance for, once the alance has been distorted. there is no ay of determining the original balance. nd. even more dangerous. recordings in be made this way to suit individual ieories. if not simply to better sales.

Columbia Records. which began a World Library of Folk and Primitive usic" some years ago. has not added it lately. presumably from lack of adeiate response. It is true that schools ke an active interest in the excellent t. but the problem is one of the new upermarket approach" to record disbution. where a fast turnover is more iportant than a good selection. Noneeless. Columbia has an excellent setion of subjects in its "World Liary." and good or even better records its general catalogue.

Westminster. similarly. has an excelit series of records. although specialng in folk rather than in primitive isic. This house has chosen to deal with rticular diligence—and success—with ain. With other areas it deals equally ll. but in less detail.

USING these three sources intelligently. even the neophyte can trace whole development of music and its ce in human society from the earliest s. We might just as well start with ie of the most difficult-to-listen-to recls. And it is no help when the quality the recording is as abominable as in *Music of Peru* (Folkways). I have de some pretty poor recordings my- and know the difficulties involved. there seems to be no reason for the kground noises. grounding hum. and eral low quality found on this record. re must be better musical material ilable from Peru: academic accuracy o excuse for poor quality. But, genly. Folkways quality is excellent. re are always explanatory texts. with tographs. to help give the listener a er awareness of what he is hearing. spoke earlier of music as a form of rcommunication. This. perhaps. is -ly "music," but it is highly signifi-. and fascinating to listen to. *Drums ie Yoruba of Nigeria* (Folkways) indes recordings of the "talking drum" actually imitates the tonal pattern the spoken language, and the other examples will give the new listener a good notion of the high degree of rhythmic complexity he will meet even in the most primitive areas. Other African records by the same company give further examples of the use of music for communication. for work songs, and for magic. Almost every African album has examples of all these elements—and among the best are *Tuareg Music of the Southern Sahara*, *The Topoke People of the Congo*—an excellent album from every point of view—and *Wolof Music of Senegal and the Gambia.*

The Tuareg album will give a good idea of some of the peculiar vocal tricks one is apt to find beyond Western shores (particularly in the final dance). The Wolof album is important in effectively demonstrating the tremendous influence of Islam in West Africa; band five of the first side is doubly interesting. not only because it is connected with the Islamic concept of the Holy War that was of such major political importance in this area. but also because of the fine recording of two small *halam* lutes.

Columbia has two albums of African music—*Bantu Music from British East Africa* and *African Music from the French Colonies.* The latter is far superior in quality and content. being drawn up under the guidance of the musicologists of the Musée de l'Homme. The East African album. from Hugh Tracey's recordings. is superficial and. one suspects. not truly representative. the selection having been made to please the ear rather than to present accurate documentation. But Columbia also has a most exciting record—*Olatunji! Drums of Passion*—in its general catalogue. Here is a Nigerian. Michael Olatunji. a highly competent musician. who has lived many years in the United States. This record is a curious combination of his two worlds of music. The distinctive voice quality of the African male soloist contrasts strangely with the painfully cultured Western chorus. in which the sopranos are consistently out of tune.

To hear something of the magical use of music. the listener should turn to some of the records of American Indians. The drum. the whistle. and the rattle are all magical weapons of the shaman. as is the chant. I single out two records here, both by Folkways. They are *American Indians of the Southwest*, and *Sioux and Navajo Music.* These are not only technically excellent. but also contain fine music. Each record is accompanied by a good descriptive text. forming an invaluable introduction, by Professor Willard Rhodes. The Sioux love song (side one. band 2b) is enchanting, and shows well how music is best made to suit the mood of the moment rather than to conform to theoretical niceties.

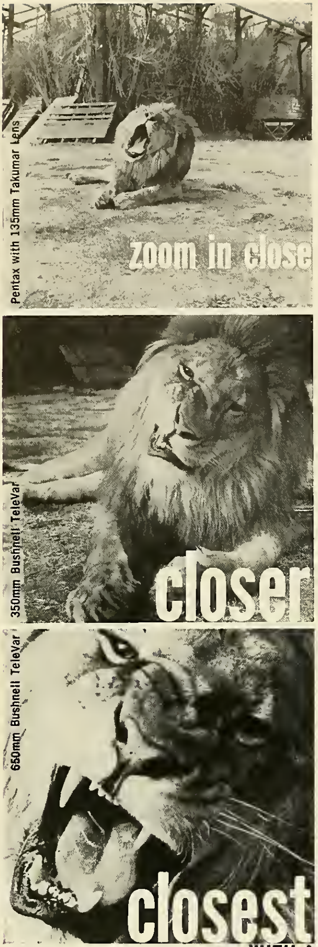
Folkways have four double albums —*Music of the World's Peoples*— but these contain only snippets from their other albums, and there is some inaccuracy in the documentation. For instance, in volume four, band 51 is marked on the record label as "Ituri Forest Pygmies: Boy's Circumcision." The text mentions nothing about circumcision. but talks about Pygmy music in misleading generalities. To complete the disaster, it is actually a BaNgwana tribal version of a Nyamwezi song from Tanganyika!

THE transition from the borderland of primitive music to that of folk music can perhaps best be made by listening to some Oriental music. Again. to start with the hardest. I would suggest two Folkways records: The first is *Traditional Dances of Japan*, because the very first number sets a magnificent atmosphere that is half the battle in listening to any exotic music. The record is a real listening experience and. together with the written notes. it is perhaps as descriptive as any documentary film. If the neophyte thinks the percussion tends to overbalance the voices, he should resign himself to this authentic fact of musical life. Next, I would suggest listening to *The Ruse of an Empty City*, a fine piece of Chinese folklore in the guise of opera. In this way historical fact is preserved in many parts of the world. and it is an experience to follow this particular drama. blow by blow, with the aid of the translated text. In a way. to listen thus is a great deal easier than to watch Chinese opera. with all its visual distractions.

If the listener's interest in Oriental music is thoroughly whetted by now. he can move in a leisurely way through Indonesia with the aid of two Columbia records. *Indonesian Music* has as its main virtue, perhaps, written notes by one of the world's foremost musicologists. Jaap Kunst. Then move on to a record that offers much better listening: *Dancers of Bali.* The beginner can easily detect a definite change of musical style. not occasioned solely by the distinctive *gamelan* orchestra. The difference is accounted for by the fact that Bali was once part of the old Javanese Hindu Empire, and still retains many cultural traits of Hindu heritage, particularly the music.

This brings us to an essential in the study of folk music. the music of India, which heavily influenced the Greek world in style and concept. Columbia has two good records. The first, *Indian Folk Music*, was recorded by Alain Danielou. Professor of Music at Banaras Hindu University. It presents many different styles of music. and the commentary is written in a lucid, if somewhat dry manner. The second is simply called *The Sounds of India*, and contains spoken

MR. TURNBULL, an ethnologist with THE AMERICAN MUSEUM, has long had a deep interest in primitive music.



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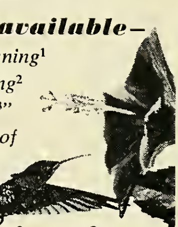

Hummingbirds

by Crawford H. Greenewalt

➡ For all who were unable to obtain copies of this exquisite volume when the initial printing sold out so rapidly last fall, a second edition is now available. Published under the auspices of the American Museum of Natural History, this splendid portfolio of high-speed color photographs — with lucid text, drawings, and charts — is sure to delight naturalists and bird-watchers, as well as connoisseurs of the book-maker's art.

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commentary. This is an admirable record: the instrumentalists are among India's finest: Ravi Shankar plays the *sitar*, Chatur Lal accompanies him on the *tabla* drums, and N. C. Mullick on the stringed *tambura*.

Following this, I recommend a particularly beautiful record, *From the Land of the Golden Fleece* (Columbia). Produced in Greece with the Greek Folk Dances and Songs Society, this is an important and authentic document, and it shows clearly how strong the Oriental tradition is in Greece, even today. On side one, band 6, there is an exquisite soprano solo, "Nanourisma," which illustrates the point as well as any.

If one wants to dally further with European folk music, there is no dearth of records put out by all three companies: it is difficult to single out any for special mention. Westminster, however, has a detailed, competent, and enjoyable coverage of Spanish folk music (and of Neapolitan, Hebrew, and Armenian). Columbia's *The Folk Music of Southern Italy* is one of its best, although one suspects that certain effects are achieved for the listener's benefit. I prefer Folkways' documentary point of view. They, for instance, unashamedly present *Flamenco Music of Andalusia*, shorn of its push-button glamour. There is good singing, with a good guitar, and some exciting dances on the second side.

In records of Western music, we can look for (and find to varying degrees) music still playing its various roles as accompaniment to manual labor, as a means of passing and preserving news, or as a method of instilling moral virtues in the minds of the listeners and participants. But it is generally dissociated from religion. Yet this is an artificial dissociation, and it is not amiss to point out that a great many classics—even those designed for sacred use—contain folk themes. Even more to the point, we should acknowledge that the differentiation between sacred and secular music is also one that is largely a product of our own peculiar development.

In considering the role of music in religion, the Folkways religious series should be discussed. It covers religious music of various Christian sects, of the Jews, Moslems, Sufi, and Japanese Zen Buddhists. It includes a documentary recording of Easter Day festivities in Jerusalem and of the Mazatec mushroom ceremony. All are worth listening to, and our appreciation of other peoples' music grows with understanding of their ways.

After returning toward home ground via Westminster's *The Armenian Mass*, we can appreciate even more the direct connection between music and religion and its use as a means of communion when we listen to the Masses of Palestrina or Bach or to Mozart's *Requiem*. And at the risk of certain accusations may I suggest that the reader listen to Folkways *The Pygmies of the Ituri Forest*, with notes by myself, telling how music is used in exactly this way—as a direct form of communion, even without words, between man and God. And this represents man at his most primitive!

But there is only one record with which to end this discussion. If I were to recommend one record above all others, t would be Columbia's extraordinary ind exquisite recording, *Arias, Anthems ind Chorales of the American Moravi- ns.* This is the first in a series, "The Jnknown Century of American Music," overing the period between 1760 and 860. In my regrettable ignorance, this ecord was a total revelation, and one of ny most exciting experiences in the vorld of recorded music.

The Moravians are, of course, of Ger- nan descent. They have now been estab- ished in this country nearly 300 years. Vhen they first came, they brought with hem two things: a gentleness of nature hat was manifest in religious tolerance t a time when such tolerance was not ommon, and a positive musical fanati- ism. But the music they brought with hem did not just stagnate, nor did it re- iain purely German in character. For ie Moravians, music was, and still is, ie living thing it was to earliest man. nd so it lived and grew with them, enriching their lives and now, thanks to Columbia, waiting to enrich those of others. It has all the magnificence of Bach, with much the same degree of depth and sincerity; and it has overtones that are almost Italian, abounding in youthfulness and vigor. Yet in character it is part of the American heritage.

The brasses, strings, woodwinds, and organ combine with the choir to give a near perfect performance of this very lovely music, and the essence of this beauty lies in the fact that the Moravians recognize what our ancestors did—and what primitive man still does—that between the sacred and the secular the line is artificial and arbitrary, and that music is one of the surest ways of uniting the two into a single whole. The Moravian attitude is summed up best in a story quoted on the record's jacket.

A New England divine questioned a Moravian youth, following a Saturday concert (which seems to have been almost as obligatory to Moravians as Sunday Church), as to whether he would use the same instrument in the divine service of the morrow that he used in the profane concert of the day. The serious-minded young Moravian, not seeing his life divided in this way, replied with another question: "And shall you, sir, pray with the same mouth tomorrow with which you are now eating sausages?"

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WP6012	Neapolitan Folk Songs
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XWN18080	Spirituals: The Tuskegee Institute Choir
WST15029	Spirituals: Graham Jackson Choir

RELIGIOUS MUSIC

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FR8990	The Way of the Eiheiji (Zen Buddhist Ceremony)
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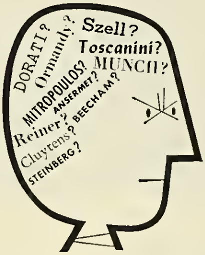
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The Rim of the Ree

Calcareous algae occupy a major role in the growth of ato s

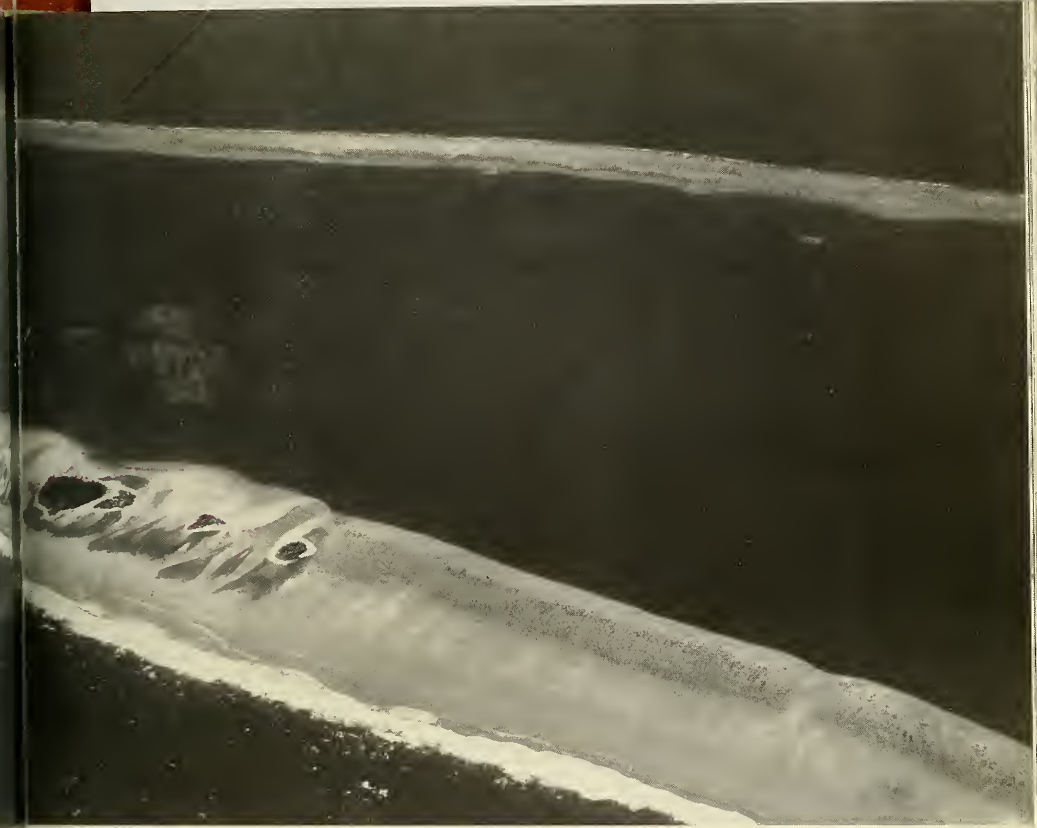
By E. Yale Dawson

Dredge down! The gears of the bow winch mesh; the great spool turns, and the steel cable pays out as the biological dredge is lowered into the tropical sea. Fifty fathoms below is a submerged, flat-topped mountain, the Gorda bank. We are here to seek what lives on that submarine butte.

So it was, twenty years ago, when the research vessel Velero III was exploring the strange biota of the Gulf of California. I was, as a fledgling marine botanist, witnessing dredging from a ship for the first time in my career. We were over the bank, and now were blindly scraping off a bit of its surface to bring to light the creatures of the dim sea floor, almost at the uttermost limits of light.

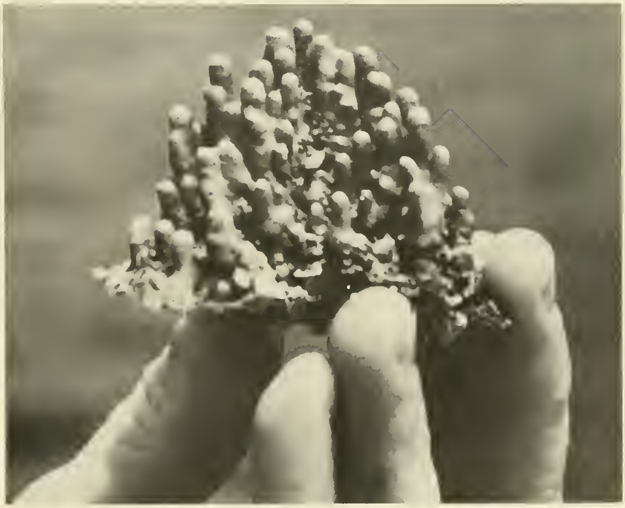
The dredge came up full. Its great bag-load, bulging within a protective chain skirt, was poised for a moment over the sorting screens. The closing cord was cut, and out poured a pile of shiny nodular pebbles, each an inch or two in diameter. But these were strange stones indeed, covered with warts and knobs, and all of a rose-pink color. In fact, there was not a stone in the lot. This was a dredge load of plants—stone plants of the sea- he calcareous red algae known cc ec- tively as nullipores.

In the days of lace cuffs and w- dered hair, these curious plants re generally considered to be some nd of inorganic, stalactite-like form. ey found their way into "collector's b- inets" of the time along with c ls. worm tubes, walrus tusks, and er novelties of the sea. Linnaeus tr ed them as coral-like animal forms In- deed, Lamarck coined their na e— *nullipore*—to distinguish these f ms "without visible pores" from the or-



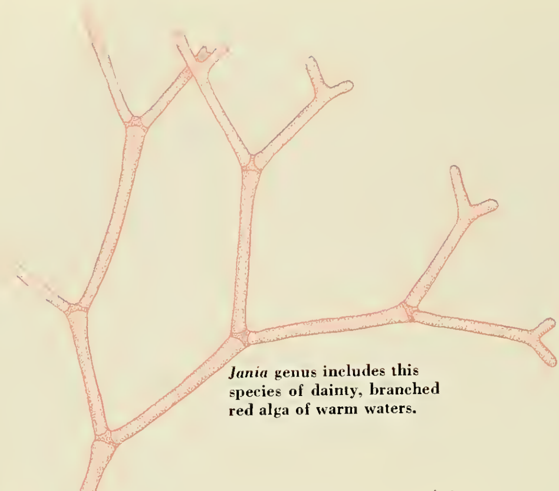
AIR VIEW of Marshall Island atoll, *above*, shows surf on reef's algal rim, and tiny islets built upon the reef flat.

NULLIPORE FRAGMENT, *below*, typifies one of the many kinds of stony plants that grow on seaward margins of reefs.

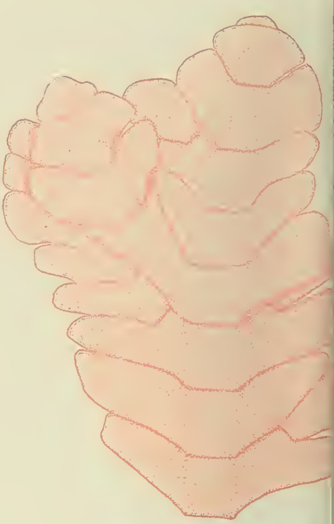


ıs corals. It was not until 1837 that
e stones were finally and positively
cognized as once-growing plants.

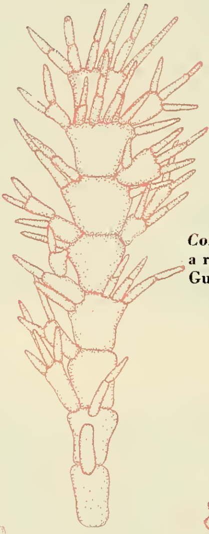
Today we recognize calcareous
rms in each of the three major
oups of marine algae—the green
lorophyceae, the brown Phaeophy-
ae, and the red Rhodophyceae.
mong the green algae, calcified
rms occur only in a few families,
rgely confined to warm seas. Indeed,
latively few genera and species of
een algae are calcareous. Nonethe-
s, in their tropical habitats these
ants are often remarkably abundant,
d sometimes are among the most
nspicuous members of the local ma-
e community. Thus, on some of the
ntly shelving, intertidal flats of Oki-
wa, one wades ankle deep in a veri-
le meadow of *Acetabularia*—acre
on acre of almost pure stands of
se remarkably beautiful little green
rasols. In the sandy bays of Cuba,
Bahamas, and south Florida, one
ds an abundance of the strange Nep-
ne's Shaving Brush (*Penicillus*), the



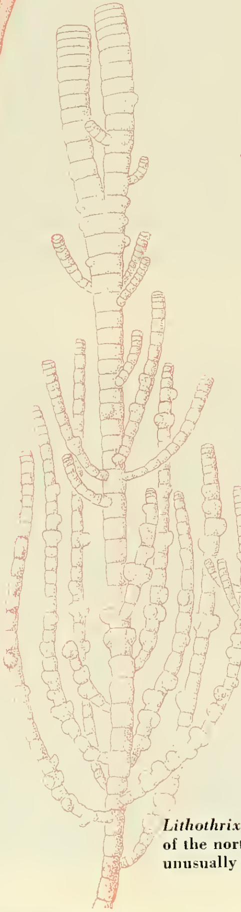
Jania genus includes this species of dainty, branched red alga of warm waters.



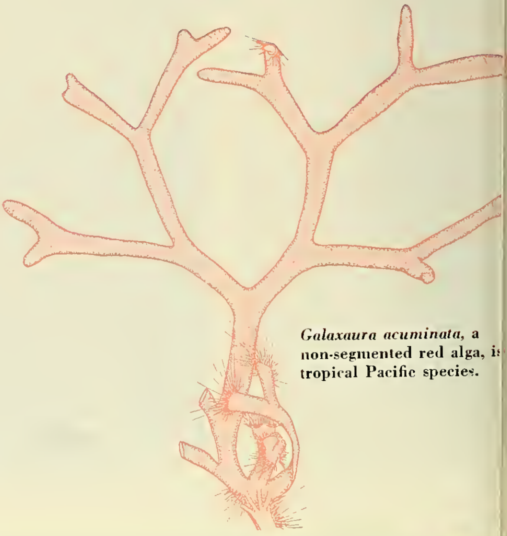
Bossiella, with segments of wingnut shape, is found in California coastal waters.



Corallina polysticha is a rare, jointed red alga from Guadalupe Island, Mexico.



Lithothrix, a red alga of the northeast Pacific, has unusually short segments.



Galaxaura acuminata, a non-segmented red alga, is tropical Pacific species.

little Christmas-tree-like *Rhipocephalus,* and the delicate green, fanlike *Udotea.* Among the coral heads and rubble flats on the bottoms of the vast atoll lagoons of Kwajalein or Eniweok, mounds and mats of *Halimeda* grow in such persistent plenty that the agoon floor sediments are largely built up of the accumulated fragments of these jointed plants.

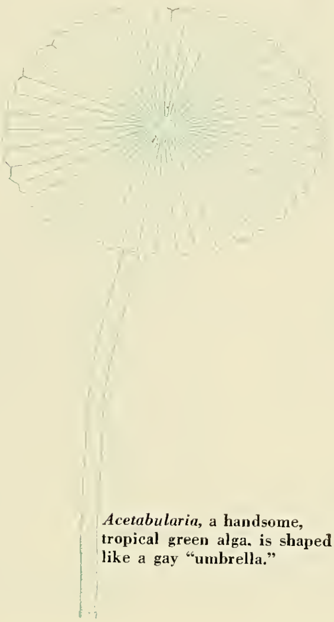
THEN there are the strangely and intricately fashioned species of the family Dasycladaceae: *Dasycladus, Bornetella,* and *Neomeris.* These are iny little plants, often inconspicuous, but sometimes the most striking members of an undersea flora. I remember living one day in a warm island lagoon in the Gulf of California and being impressed by great, round boulders on the bottom that were studded with little, glistening, upended "worms" of a brilliant emerald color —the green alga *Neomeris.* Many nembers of this family are known rom the fossil record: they are hought to have contributed to the fornation of limestone rocks.

Among the brown algae, calcareous pecies are few, and confined largely o the tropical genus *Padina,* whose inresting, fan-shaped representatives ay be found in almost all warm seas. *na* commonly has concentric s of superficial calcium carbone, alternating with bands of delicate low-brown hairs: underwater, they ometimes stand out as the most graceully formed and artfully patterned lants of the sea floor.

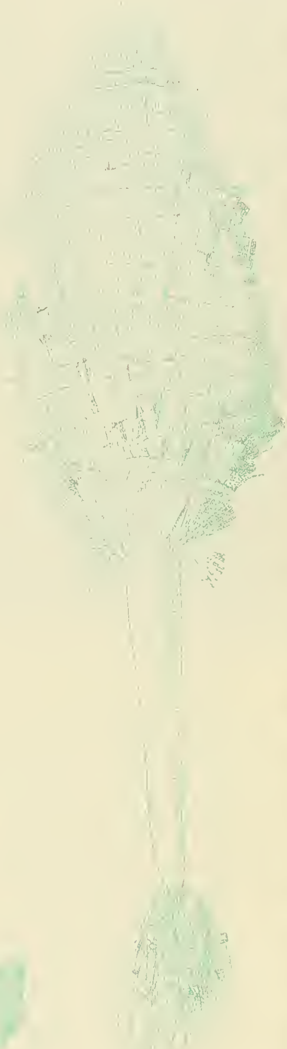
In red algae, as in the other two roups, the occurrence of calcified rms is limited to a few families. But ere, one of these families—the Corallinaceae—is of wide distribution. The nly other important calcareous genra of red algae are *Galaxaura, Liaora,* and *Peysonnelia.* These occur ostly in the Tropics, but are seldom oundant or conspicuous.

Thus, the Corallinaceae includes the erwhelming majority of the calcarous plants of the world. They occur om the Arctic to the Antarctic and om the highest and most inhospitae intertidal levels to the cold, dim pths of ocean at the extreme limit of ht penetration. Sometimes a score of ecies may live in a single habitat. gain, one species may dominate a reon to the near exclusion of other rms of vegetable life.

Despite the rigidity and often brittle



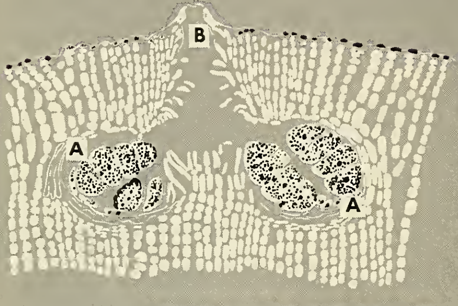
***Acetabularia,* a handsome, tropical green alga, is shaped like a gay "umbrella."**



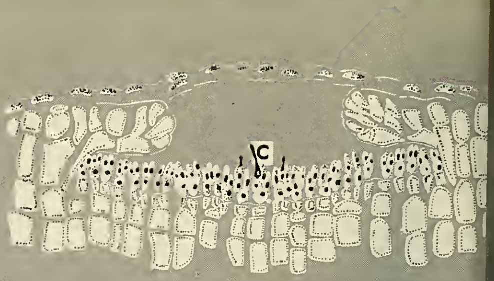
***Rhipocephalus* is a small, "treelike" green alga found on the Caribbean shores.**

***Halimeda*'s hard, stony segments compose much of the sediments in atoll lagoons.**

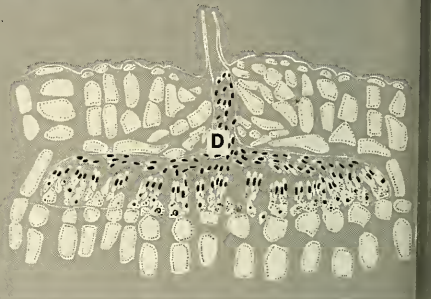
REPRODUCTION OF RED ALGAE



Lithophyllum, a calcareous red algae, reproduces by an alternation of generations. Here, tetraspores (A) form in conceptacles borne on non-sexual plants, and are then released into the water through exit pore (B) in cavity.



Tetraspores grow into separate male and female plants. Larger female conceptacle produces reproductive organs called carpogonia (C, *above*). Meanwhile, the conceptacle of male plant, *below*, discharges non-motile spermatia (D).



character of many calcareous algae, the structural differences from the usual, fleshy forms are essentially eliminated by the application of a few drops of hydrochloric acid. Removal of the carbonate reveals the typical cellular structure of the plant, hitherto obscured by encrustation.

The stony material laid down by the living cells of the plants is largely calcium carbonate. This takes the form of calcite in the Corallinaceae and of aragonite in the other red algae, although some magnesium carbonate is present. While the encrustation first appears in pectin-bearing layers of the cell walls and then extends into the cellulose layers, the living protoplast of the cell always remains enveloped by an uncalcified membrane.

In the segmented corallines, some groups of cells remain completely uncalcified, thus forming flexible joints between rigid segments. Such a delicate, erect, bushy plant as *Corallina* is admirably suited to surf shock and agitation—hardly less so than is the rigid, rock-encrusting *Lithophyllum* with which it may grow.

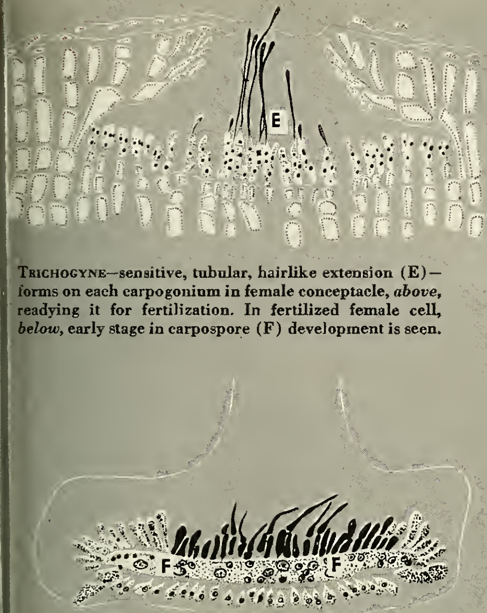
The calcareous red algae, like most of the members of this large plant phylum, fulfill their life history by means of an alternation of generations. That is to say, a given plant does not reproduce one of the same kind as itself. Instead, it gives rise to a different generation of plants, and these, in their turn, repeat the first generation. These generations are of two kinds: one is sexual, and consists of separate male and female plants. The other is non-sexual, producing spores that germinate to grow into sexual plants.

At maturity, the non-sexual plants form small, domed cavities on their exterior surfaces. These asexual conceptacles produce small, red structures consisting of four spores in a row (tetraspores). The spores are released into the water by means of one or more exit pores from the cavity. The released spores then settle down, germinate, and grow into new plants. Some grow into male and some into female plants which, except for reproductive details, look very much alike.

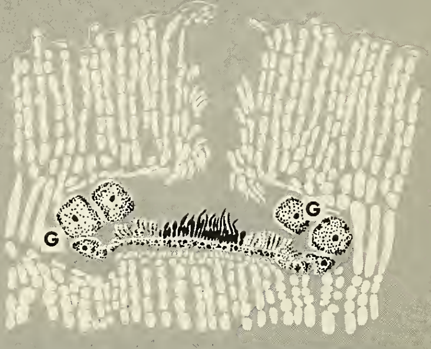
The male plants produce quite small conceptacles in which are formed exceedingly minute, non-motile, male cells (spermatia). These, usually only 2/1000 of a millimeter in diameter, are released into the water through a single pore in the conceptacle roof.

Meanwhile. the female plants ha produced much larger conceptacl , on the floors of which stand minu receptive organs called carpogon . Each carpogonium has a sensitive, tu ular, hairlike extension, called a t chogyne. This organ probes the emp space beneath the conceptacle po . waiting for the stimulus of cont t with one of the many male sperma that are then drifting freely about the surrounding water.

By what mechanism the drifti , but non-motile male cell ent s the tiny pore of the female conce acle to accomplish the sexual uni n we do not know. When a spermati a does make contact with a trichogy . however, its nucleus enters the car gonium, effects sexual fusion. and o begins the development of a new g eration. Strangely, this new generat n remains as a distinct parasitic pl t *within* the female plant. There it gr s into a small mass of cells, and p duces a special group of spores ins e the old female conceptacle. Each f these spores must now be release n its turn—through the same pore y which the male cell entered—into e sea water outside. There it find a



Trichogyne—sensitive, tubular, hairlike extension (E)—forms on each carpogonium in female conceptacle, *above*, readying it for fertilization. In fertilized female cell, *below*, early stage in carpospore (F) development is seen.



Carpospores mature (G), are discharged through pore into sea water. They germinate on some rocky surface that is as yet unoccupied, and a new generation of non-sexual plants begins to develop, starting the cycle over again.

ocky surface yet unoccupied, upon hich to spread the first cells of a ew. non-sexual generation.

Calcareous members of the red algal amily Corallinaceae are the most prevlent of the stone plants. so widely disributed that they form part of the narine flora of every maritime nation f the world. In the glacial fiords of orway or Greenland. one finds thrivng beds of nullipores. Crustose coralines cover wave-beaten rocks from amchatka to Chile. and from Newoundland to Kerguelen. Delicate, akelike forms live on the leaves of rtle grass in Cuba. and on eel-grass Japan. The jointed bossiellas dwell o less successfully in the cold. clean de pools of Vancouver Island than eside sewer outfalls in southern Caliornia. The dainty janias are equally rominent in spongy, algal turfs on e reef flats of East Africa and in ose of Micronesia. Despite the ubiuity of these plants, they have been ttle studied and remain among the ast-known organisms of the sea.

Since plant scientists have generally neglected the calcareous algae, eir importance in many natural enomena has been little recognized. This is particularly true of one of the most extraordinary of all marine geological phenomena—the tropical "coral" atoll. The story of the calcareous algae's contribution to the formation and growth of the atoll is so remarkable and so little known that it seems particularly appropriate to tell something of it here.

During the last century, a number of naturalists made visits to the coral reefs of the Indo-Pacific region and, from their observations, theories of atoll origin and growth were developed (Natural History, March, and April, 1959). Charles Darwin, James G. Dana, Sir John Murray, Alexander Agassiz, Reginald A. Daly, and others interpreted the atoll from a geological or zoological standpoint. But each investigator failed in every instance fully to recognize the importance of calcareous algae as controllers of reef development. It was not until Sir Edgeworth David's South Pacific expedition (1896-1898) that evidence was obtained to establish the significance of plants in this relationship. Since then only an occasional marine botanist has written on the subject and expanded the knowledge of the role algae play in atoll formation. As a result, some long-standing and widespread misconceptions are still prevalent.

Some of the pertinent facts are: First, nullipores have been found to be among the principal components of atoll reefs in a great majority of cases. In some instances, they are almost the only visible components, to the virtual exclusion of coral animals.

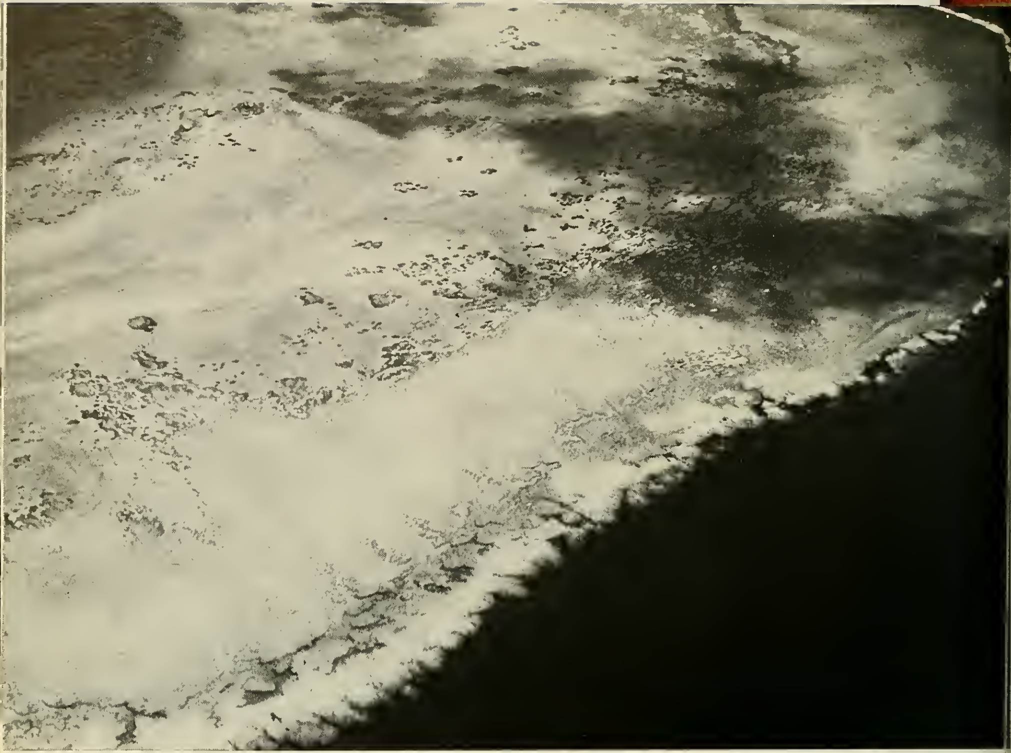
Second, the principal cementing agent in the reefs is the nullipore.

Third, calcareous algae have been found actively working at depths of six hundred feet.

Fourth, the seaward margins of actively growing atoll reefs are often covered by a pavement-like growth of *Porolithon*, a species of nullipore.

Fifth, borings to depths of several thousand feet indicate the consistent presence of great quantities of nullipore material throughout the reefs.

The most striking first impression of many atolls is their enormous size. Tens of thousands of service men have visited the vast lagoons of Kwajalein or Eniwetok, thirty miles or more across, surrounded by dots and lines of vegetation-clad islets. But these atolls have not always been so large. They grew, and are still growing.



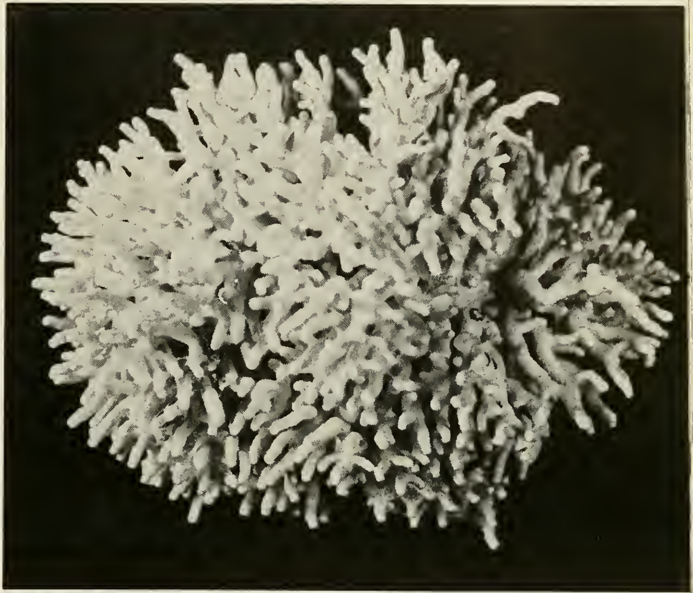
TONGATABU, in the South Pacific, is an example of combined building action of coral animals and the calcareous algae.

ELEVATED MARGIN of the seaward reef on Majuro Atoll in t Marshall Islands, *below*, is almost totally made of red alg

One also finds small atolls, such as Palmyra in the Line Group, and earby reefs, such as Kingman, that arely break the surface of the water. ll of these are related within the atoll henomenon. To understand an atoll's levelopment, it must be considered as kind of dynamic, living organism. It s. really, a vastly complex association f living things, all dwelling together a marvelous balance, each plant and nimal contributing to the life and rowth of the whole atoll and to the elicate balance maintained between onstruction and destruction.

As a possible point of departure in the development of an atoll, con- der a reef such as Kingman, consist- g of an association of coral animals d coralline algae, growing on a ightly submerged sea mount. Let us y that the reef is five acres in extent d barely breaks the surface at low de. Now, somewhat different optima r growth and persistence exist nong the corals and the nullipores ith regard to the surf that breaks er the reef. The rigid. branched, ittle corals tend to break and frag- ent under severe wave action. But the assive, reef-forming nullipores are affected by the pounding surf. In ct, the stronger the surf the better ey grow. for one of the principal fac- rs for their growth is the availability oxygen for their respiration during e dark hours of the night, when their otosynthetic pigments are inactive. Accordingly, on this five-acre reef, e first organisms to grow above the ter surface, creating a condition of rf, will also create conditions that d to favor the growth of the nulli- res and to reduce the upward exten- n of the coral. Herein begins the mation of an atoll from a reef, for nullipores grow into the breaking f. As they do so. the intensity of the f becomes greatest around the mar- s of the reef. Here the nullipores w upward and form a rim slightly ve sea level. This rim, which breaks impact of the waves on all sides, vides a relative calm over the inner t of the reef. If the sea level is ris- . or the sea floor subsiding, a la- n develops within the slightly vated ridge, aided by the destructive cess of solution resulting from the ion of carbonic acid derived from respiratory carbon dioxide pro- ed by the life of the lagoon.

he rate of outward growth of the



Branched species of ***Porolithon*** **is a red alga that contributes to formation and growth of the atolls in the Pacific.** ***Porolithon*** **are usually pinkish in hue.**

Recently discovered calcareous alga is ***Lithophyllum reesei*****, found on the west coast of Mexico. Shapes of algae are nearly as numerous as are species.**

An oceanographer and botanist, DR. DAWSON is now the Resident Director and Vice President of the Beaudette Foundation for Biological Research.

reef margin reflects differences in surf and in available growth nutrients, due to wind and currents. As a result, the young, dynamic atoll usually takes on a somewhat elliptical shape.

Reef margins are extended seaward in three ways: by the growth and cementing action of the nullipores, by the often profuse growth of corals on the outer front, or face, of the reef below the surf zone, and by the infinitely slow build-up of a vast talus slope of nullipore and coral fragments to the abyssal sea floor. Whenever the reef ridge dissolves down to a level that permits the sea waves to pour in over it, the increased supply of oxygen for nighttime respiration encourages the growth of the pavement algae by which it is built up again.

THE seaward advance of the nullipore ridge, whose height above sea level is controlled by desiccation, leaves behind it a reef flat that stretches between the ridge and the central lagoon. Storms cast up boulders and debris from the reef margin and the talus slope onto this reef flat.

Until such a pile of sand and rubble appears on the reef flat, all rain water is dissipated into the open sea. With sufficient material to confine it, however, the fresh rain water stands in the sand at sea level, floating on the salt water below it, and mixing only very slowly. As a pool of fresh water forms in the sand, seeds (carried to the islet by wind and sea) sprout and penetrate to the water supply, and thus the island vegetation comes into being. Sea birds come: as they feed on the fish of the reefs and lagoon, and nest in the vegetation, they convert animal life of the sea into fertilizer for the land. The birds thrive, trees and shrubs grow, and gradually humus forms on what at first was only barren sand and rock.

In all of this islet growth, the calcareous algae play an important role, spreading their crusts over the rubble and the sand, cementing and binding the reef margin, and advancing—ever so slowly, but steadily—into the waves.

LUSH VEGETATION on Palmyra Atoll, in Line Islands of Pacific, is rooted in the reef flat's calcareous sand and gravel.

THE AMERICAN BALD EAGLE

Despite protection, this wary bird cannot co-exist with man

By George Heinzman

ALTHOUGH the American bald eagle, *Heliaeetus leucocephalus,* became ur national emblem 179 years ago, he bird has received little protection ntil recently and is now greatly reluced in numbers. Alaska and Florida re the principal strongholds of a ange that once included virtually very state. Even in Florida, of an esimated 500 active nests a few years go, some observers believe that only 50 are occupied at present.

While studying nest sites in Florda, I learned that the bald eagle is un-shy despite its legal protection. n invisible circle, with a radius of 50 to 300 yards, seems to exist around ost nests observed. Outside the permeter of this circle, I could observe nd photograph the birds openly withut unduly disturbing them. Three teps inside it, and they flew, making heir squeaking cry of alarm.

Eagles mate for life and are deoted to "family" matters at least half e year. The eyrie is a mass of limbs, wigs, moss, and grass, high in a pine, angrove, or cypress tree. Most nests re four to eight feet in diameter and epth. Used for years, they may beome tremendous. Charles Broley, lorida's famous eagle bander, reorted a record eyrie that was twenty et deep and nine feet in diameter.

Nesting starts in Florida from Sepmber to November. Adults refurish the eyrie for roughly a month efore depositing one to three eggs, hich incubate about thirty-five days. he young are covered with light tal down that is replaced in three eeks by heavy gray "wool." From e fifth to eighth week, they acquire rk plumage, which shows only scatred lighter shading until the fourth fifth year, when the maturing birds tain their white head and tail.

Florida nests rarely contain more an two eggs, with an average of out 1.5 birds fledged per nest. One tling usually dominates the peck

ALD EAGLE reigns above its eyrie, *left,* op an 80-foot dead pine in Florida.

PERCHED ON A LIMB to left of its nest, *above*, eagle assumes watchful stance. It calls, thrusting the head forward, *below*, in seemingly defensive gesture.

ALERT POSITION is maintained, *below*, although eagle has shifted to a higher perch. Male bald eagle is warier than the female, is first to flee if approached.

Talons extended, an eagle takes off from the tip of a limb near its nest.

Broad wings of adult eagle support a weight ranging from 8 to 12 pounds.

Unusual view of flying eagle sho
wings half-closed and the tail fanne

order and receives the most food and attention. Often the second nestling dies of neglect and abuse.

Eaglets use the eyrie for practice flights—flapping hops into the wind—and make their first successful flight about the twelfth week. This usually occurs from February to April. I have seen parent birds entice the young to try their wings by approaching the nest with a fish, then veering off, until the young take to the air. The parents stay near the nest, feeding the young, for perhaps a month more.

During the summer many eagles go north, even as far as Canada. However, evidence uncovered by Dr. William B. Robertson, a Park Service research biologist in the Everglades, shows that not all eagles wander. Some stay in Florida all year, usually living away from the nest in summer.

Depending on the availability of other food, fish constitute 65 to 90 per cent of the eagle's diet. This is supplemented by snakes, wounded waterfowl, carrion, and small mammals. An adult eagle weighs eight to twelve pounds and has a six- to eight-foot wingspread. The male is slightly smaller than the female, but the difference is apparent only when they are seen together. He is also warier, being the first to fly if approached. Tests show that captive eagles can carry about five pounds, but wild ones may be able to lift twice as much.

The Audubon Society is attempti
a nationwide census to determine re
sons for the eagle's decline and t
countermeasures to be taken. Dr. R
ertson, making a long-term study
Everglades National Park, has be
watching about 60 nests. He suspe
much of the eagle's observed failu
to reproduce in certain parts of Fl
ida may be caused by natural steril
owing to age, by the tendency
many eagles to "vacation" from fa
ily-raising for a year or so, and
human disturbances during incul
tion and nesting. My observations
35 central Florida nests support th
Remote nest-rearing was 65 per ce
successful, compared to 6 per cent
nests near human activities.

Poised for take-off, eagle raises its wings for powerful downthrust. Captive eagles have flown with 5-pound loads.

Now airborne, eagle wheels sharply and flies past per
In summer, some Florida eagles go as far north as Cana

Mr. Heinzman's report on the bald eagle is based both on research and extensive observations in the field, where he made the photos seen here.

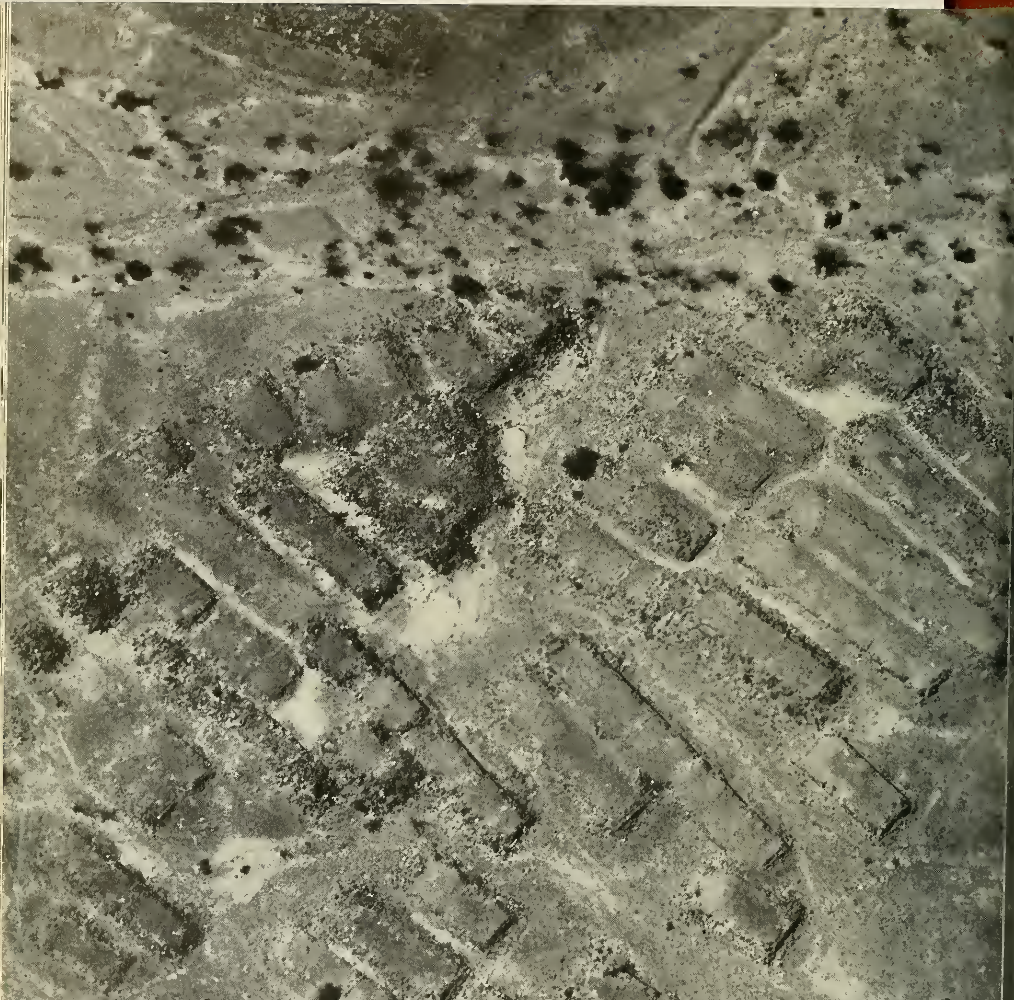
The bald eagle has somewhat spe- ılized environmental needs—good hing water, and tall, sturdy trees th solid crotches to support nests t may weigh hundreds of pounds. in has altered the eagle's environ- nt drastically by cutting most tall iber and draining much fishing ter. Throughout Florida, towns e been built beside inlets and bays l around inland lakes, depriving eagle of thousands of square miles fishing water, since the bird has not rned to co-exist with man. Individ- s may remain in an area a few rs after man's intrusion, for the ds seem doggedly determined to ain old nest sites. But their produc- days are over: man's activity near nest prevents giving the young the e needed for successful rearing.

ature dealt a severe blow, too, in 0 when hurricane Donna lashed rida in early September. Observ- r by plane, Dr. Robertson found 90 cent of the eagle nests destroyed he Florida Bay section of Ever- les National Park. Other parts of state were less damaged. My ob- ations show about a 30 per cent in central Florida. By December, Robertson found rebuilding at -thirds of the destroyed nests, but rate analysis of long-term dam- is impossible. For comparison, r a mid-October hurricane in 1944, ley reported that 64 of 65 de- ved nests were rebuilt. But in only er cent of the nests were young d successfully the first year, as pared with 70 per cent success the before. Donna, hopefully, may e to have had a lesser effect.

W HAT lies in the future? Most of Florida will go the way of the na- Some breeding stock will remain mote parts, but the species will be erously near the point at which iving birds will be so few that ause of inbreeding, sterility, and ration of the survivors, plus other mental factors — replenishment mes impossible. The American eagle's last hope south of Alaska s to be in the Everglades National and central Florida cattle lands, e ranchers—proud of their avian ıts — protect them scrupulously.

Young eagle, *above*, about 10 weeks old, rests on rim of the nest, facing into wind. *Below*, eaglet spreads its wings in a rehearsal for first flight.

Eaglet preens, scratching head with foot, *below*. At this stage in eagle's life, feathers are predominantly dark. Head and tail feathers lighten later.



Baluchistan Find

Ruins of a 4,000-year-old culture still stand in West Pakistan

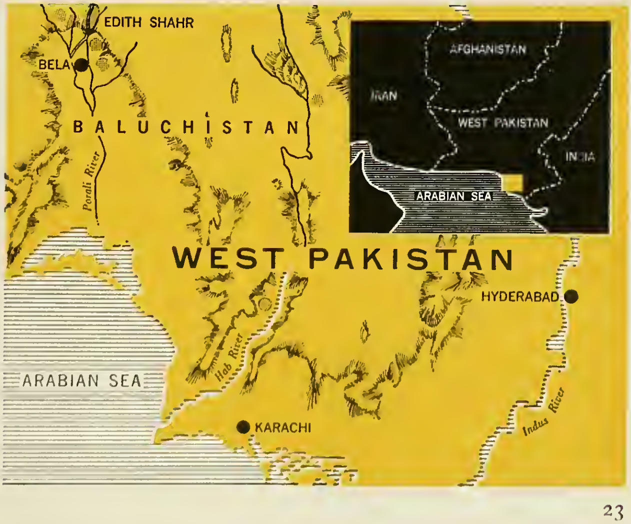
By Walter A. Fairservis, Jr.

FEW PLACES REMAIN IN THE WORLD where the archeologist can en-ounter formerly unknown ancient uins of enormous extent. Nineteenth-nd early twentieth-century travel nnals are replete with wonderful sto-ies telling of the discovery of Uxmal, Iacchu Picchu, Petra, and Angkor Vat. But today, aided by aircraft and utomobiles, archeologists have filled ost blank sections of the earth's aps so far as spectacular surface ites are concerned. It is remarkable, erefore, that in the winter of 1959-960 in the district of Las Bela in est Pakistan an American Museum f Natural History party encountered, irtually intact, previously unknown ettlements that date from the second illennium before the Christian era.

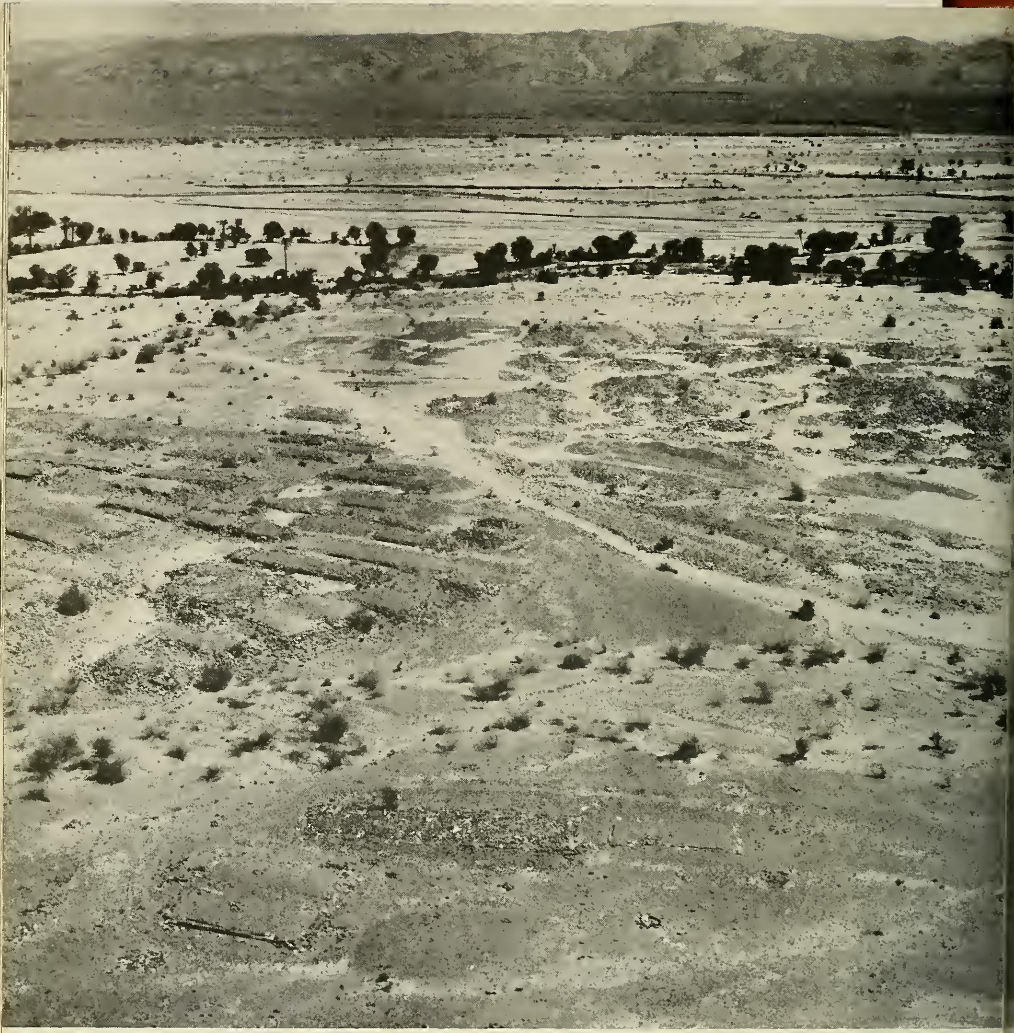
For approximately eight miles in is region, the stone walls of ancient uildings can be traced without put-ng a shovel in the ground. So well reserved are some of the ruins that ne can walk along ancient streets at are flanked by buildings, the alls of which frequently rise above ur feet. There are steps leading onto e structures, and occasionally a ved ramp indicates an ascent into a rmal building. Scattered about are agments of pottery that help to date e ruins; and sometimes one discov-s bangles, animal figurines, and ts and pieces of alabaster vessels—all which are evidence of an origin in mote antiquity.

The discovery lies in the northern-ost portion of the wedge-shaped dis-ct of Las Bela. The widest part of e wedge is a stretch of the Arabian a coast just west of Karachi. The rrowest portion extends a finger of uvium into the southeastern por-n of the Iranian Plateau, here lled Baluchistan. The district is thus surrounded by mountains on all sides but the south. The apex of the wedge is gathered in the valley of the Porali River, which drains southward out of the mountains of Baluchistan. It is one of the few perennial streams in the entire region to the west of the Indus River Valley, and the delight of its waters is enhanced by contrast to the desolate surroundings. The capital of Las Bela is Bela, a small town close to the Porali River, about two miles south of the site of the discovery. Bela retains much of its ancient aspect. This is a town with palaces, mosques, high-walled houses, and a fine, covered bazaar. It is situated in the midst of a ten-mile square of intensely cultivated land that provides a lovely setting of old trees, broad fields of mustard and of grain, and fine date palms. Nowhere else in all Baluchistan are the cattle so fat and healthy.

People have been drawn to this region because it is one of the few widely cultivable areas in Baluchistan. To the west the mountain wall is broken by the Jhau Pass—one of the most important in the Indo-Iranian borderlands. Through this pass Alexander marched his men on their return from India. Much later, during the eighth century A.D., Arab armies under Mohammed Ben Kasim moved through the pass from the west. These armies eventually conquered Sind and thus began the Moslem impact on India. Haroun, one of Kasim's generals, has a tomb at Bela—a lonely reminder of this important period in Indian history. In 1838, a British naval officer, Commander T. E. Carless, explored some of the canyons found in the mountains north of the cultivated area. In one of these he came upon a large number of artificial caves cut into the cliffs. Many of the caves had doorways and steps, and within were niches (presumably for lamps) and small storage areas. Carless' description of the strange caves was the only one until the great Asian explorer Sir Aurel Stein visited them in 1942. Stein also found several pre-



RIAL PHOTO shows intact settlement Edith Shahr site in West Pakistan. ese ruins date from about 2000 B.C.



ANCIENT SETTLEMENT at left, *above*, is same one shown on p. 22. At right are "temple" mounds. In the backgro d. beyond trees, is Porali River Va ey.

A NARROW STREET between buildings is viewed by expedition members, *below*.

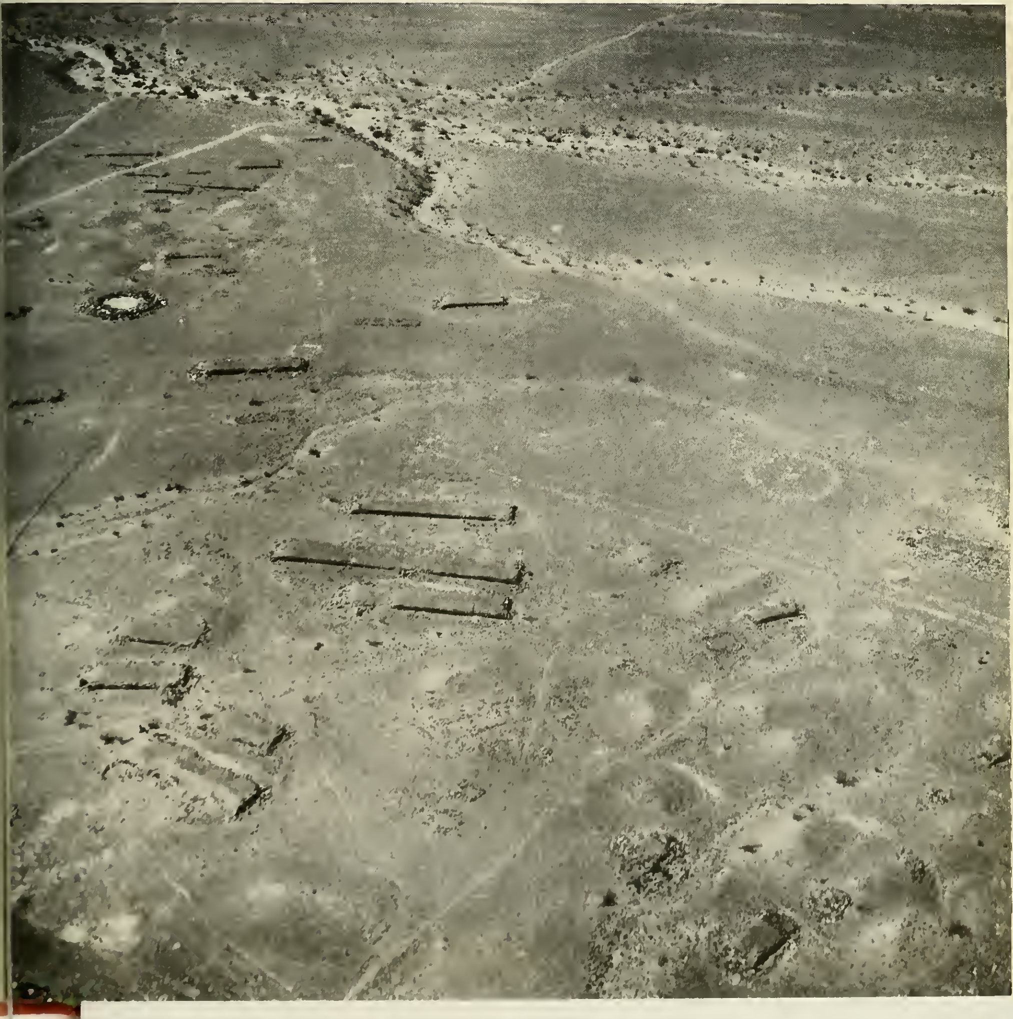
historic sites in the area. Unfortunately he died before a report could be prepared for publication.

Thus, for a number of reasons, Las Bela district has been worth archeological investigation. These reasons are emphasized further by Las Bela's geographical situation just west of the Indus Valley, on one of the high roads between the Near East and India along which the ideas and traits of earliest civilization had come. Previous archeological work in Baluchistan has indicated that in prehistoric times these areas were occupied by primitive farmers who came f m Iran. probably first in the late th millennium B.C. Later, farming il- lages became more numerous as p- ulations grew, and control of the nd for agriculture became firmer. y 2000 B.C. these village cultures d become quite elaborate and appe to have had a formal religion, with n- umental temples amid village ho s

MOST stages in this develop nt have their equivalent in pr is- toric Iran, to the west. They indic a steady pulsation of new ideas and er-aps new people moving eastward ver a period of some 1,500 years. The ranian influences did not stop in Baluchistan, however, but moved on, penetrating into the Indus Valley.

ON the rich alluvium of the Indus came a parallel development, the arlier stages of which still escape the rcheologist's spade. Later stages, owever, are illustrated by the world-amous Harappan civilization, third f the great civilizations of ancient imes. This civilization has been nown since the 1920's, principally ecause of the excavation of two of s largest cities: Mohenjo-daro, in ind, and Harappa, in Punjab—both

WHITE STONES, *above*, 8 to 10 inches high, are part of large ring. Similar stones form avenues and circles, *below*, among Edith Shahr Complex B remains.

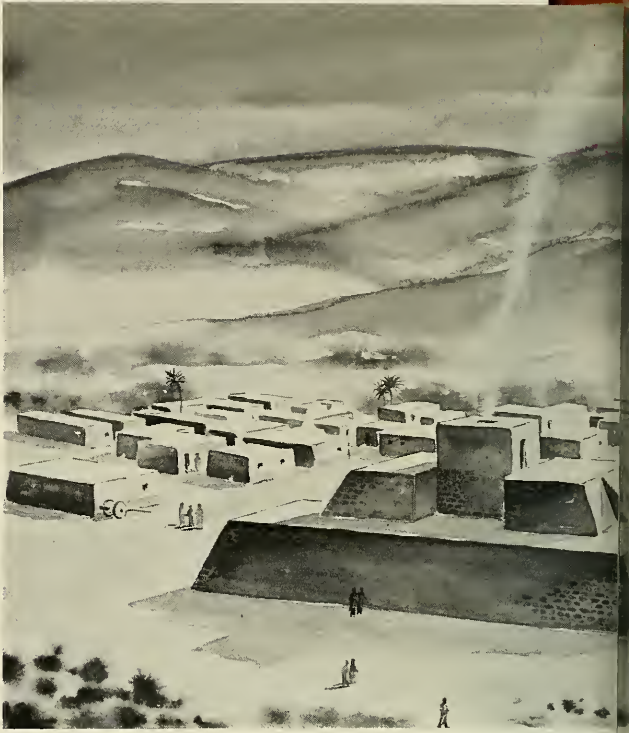


part of West Pakistan now. Town planning, drainage systems, fired brick, and cotton cultivation are some of the contributions to man's advancement made by this remote civilization. Most people of the Harappan civilization lived in villages that clustered round urban centers—the hubs of their ceremonial life. This contrasts with the life of the Sumerians, their nearest civilized neighbors. Most of the Sumerian people lived in cities, few in villages. Obviously the pattern of living was drastically different between these civilizations. The Sumerian civilization tended to be more dynamic and unstable; the Harappan, in its more rural setting, more durable and calmer. In this sense, at least, we have a fundamental division of early civilization that seems to presage the essential differences between East and West that have been so overcelebrated by writers in modern times.

UNQUESTIONABLY, the idea of civilization came from the ancient Near East to the Indus Valley. In fact, a number of authorities have pointed out exact parallels among such characteristics as architecture, seal form, certain crafts, and very probably the hierarchical government. Harappan civilization is nonetheless overwhelmingly Indian in character and quite distinct from its nearest civilized equivalent in Mesopotamia.

Obviously something had happened to civilization both in its journey eastward and in its development in an Indian setting. At this point in our researches we know little of these factors. The discoveries in Las Bela are, therefore, of more than a little importance, for they represent the development of a settlement whose density of population and architectural accomplishment approach—if they did not actually achieve—urbanization. This concentration of men and resources in one of the areas outside the classic river valleys of early civilization is extraordinary. One might well ask what criteria one can employ to decide what constitutes civilization and what does not. These new discoveries give some answers to such queries.

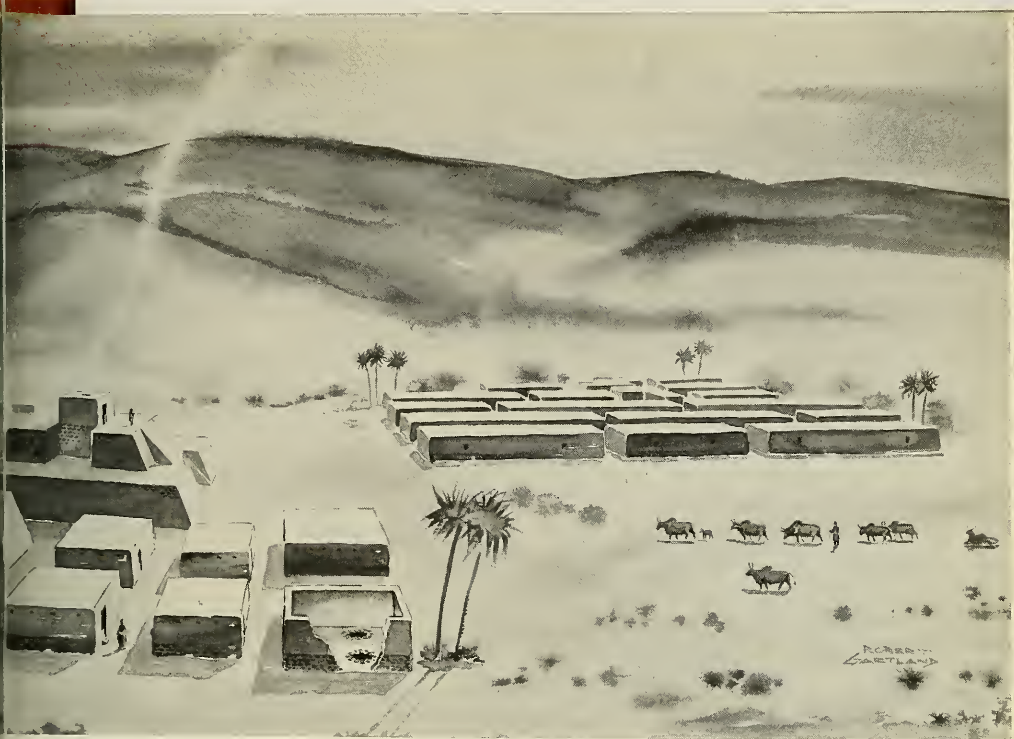
On New Year's eve of 1959, the writer, in company with Dr. and Mrs. Sherman Minton, traveled from Karachi to Las Bela to investigate the caves reported by Carless in the 1830's. Dr. Minton is a research associate of the American Museum in herpetology, and it was with more than casual interest that we entered an area so little known to both our scientific fields. En route to the caves, which are located in the Kud River area, we had to cross the Porali Valley where that river enters the broad, cultivated plains. On the west bank of the valley our path crossed close to enormous heaps of large boulders, some of them thirty feet high. These boulder "hills" blended with the boulder conglomerate slopes of the mountain beyond, and seemed at first to be a part of that landscape. However, close scrutiny revealed that these rock heaps were distinctly separate from the mountains and were, in effect, artificial. The briefest examination at the foot of these boulder hills produced a variety of potsherds that gave proof of the place's having been inhabited by man in late prehistoric time.



On the following day we visited this site again and more surprises were forthcoming. Beyond the stone heaps that stood on the east of the site, close to the mountain slopes, was a series of generally rectangular structures made of boulders laid in tiers. These structures were arranged parallel to one another so that a network of narro "streets" was formed between then

The structures are all some 15 to 2 feet wide and usually between 70 an 100 feet long. There are indicatio that they were compartmented, ar rock steps led up into these "rooms from the streets. It is very likely th there was a mud brick superstructu on these stone foundations that h long since disappeared (see the reco struction on these pages).

INVESTIGATION of the boulder hi showed that they were the re nants of monumental buildings. Th had been constructed in recedi stages, ziggurat fashion, topped by small building made of mud or fir brick. Ascent had been made by ste and ramps. In one case there was e dence of a stone drain that had be used to carry water from the top the structure. This use of drains paralleled in other parts of Baluc stan and at the great site of the Hara pan civilization. Mohenjo-daro. At t latter place, a great bath, obvious used for ritual purposes, occurs on high portion of the site. The wat could be let out through a drain.



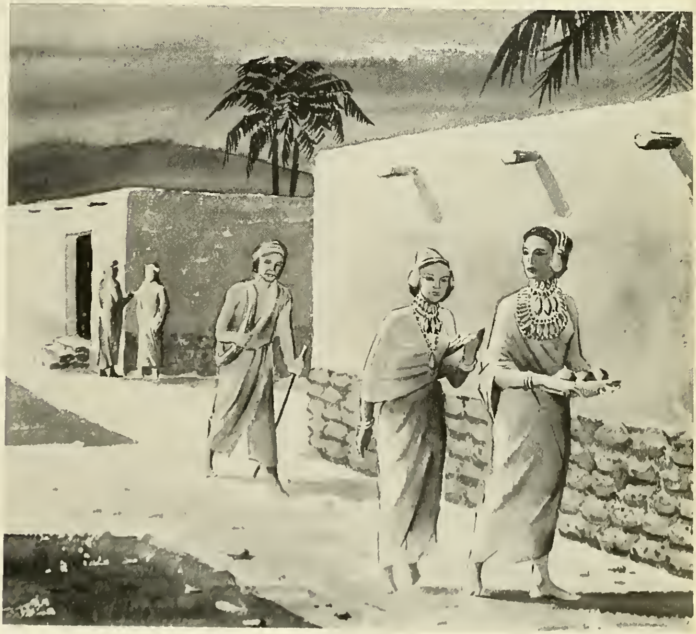
MAJOR BUILDINGS at the Edith Shahr site, seen in artist's reconstruction, *above,* were probably temples. Women, *below,* typify villagers of this period.

imilar drain system occurs in a struc-
ure—probably contemporary—found
n the Quetta Valley in northern Balu-
histan. These monumental buildings,
hen, were probably temples.

Another interesting structure was
n enormous rectangle just east of the
nain mounds. This structure is more
nan 200 feet long and about 40 feet
ide. There are traces of at least eight
ntrances, which suggest that the
uilding was some kind of communal
all—perhaps a dormitory.

The discovery of bull figurines, clay
angles. incised and painted pottery,
nd other such artifacts proves that
is site belonged to a well-known
rehistoric culture of Baluchistan
lled the Kulli culture. This culture,
its latest phases. was contemporan-
us with the civilization of the Indus
alley. Indeed. there was evidence at
is new site to reaffirm this dating.

The elaborate stone construction
d the formal layout indicate that
r site, known locally as Edith
ahr, was probably used for ceremo-
al purposes and was not merely a
rming village. This opinion is con-
rmed further by the fact that Edith
ahr turned out to be only the *south-*



ernmost of a series of similar settlements extending northward almost contiguously on both sides of the Porali Valley for more than eight miles. The sites taper off in the canyon country that leads into Kalat in central Baluchistan. Our surveys, on foot and by jeep, revealed that the now inhospitable banks of the Porali River had been thickly populated at one time. High bluffs overlooking the valley were crowned with boulder hills like those at Edith Shahr. Beyond these structures were located the settlements of those who had used the "temples."

THESE remains of late prehistoric time, which we now call the Edith Shahr Complex, are extraordinarily interesting. Unquestionably they are evidence for the existence of a specialized populace—very probably a priest community that had to be supported by the prehistoric farmers who lived in the fertile area to the south. Other contributions may have come from traders who had to pass along the valley the sites command. Perhaps a place of so many temples may have been a sacred center—a goal of pilgrimage. The rectangular structures with their parallel streets may not even have been habitations for the living. A few fragments of possibly human bone that were found on their surfaces indicate that they may have fulfilled the function of tombs.

The formal aspect of these ruins, their dominant position in the valley, their great number, and their impractical separation from areas of good, cultivable soil all seem to point to a ceremonial cult of extraordinary vitality. If these Edith Shahr sites represent a ceremonial complex—and every indication so far is that they do —then we have a clear division between the secular and the sacred that is of considerable significance to the systematic study of civilization.

IN every instance but one we have reason to call the Kulli culture a civilization. We have monumental building, hierarchical government, specialization, and even evidence of wheeled vehicles. Only writing is absent from our list. Perhaps this too will be found by future excavation and the Kulli culture will become the Kulli civilization.

Our archeological survey was replete with surprises. There was evidence here and there that the Kulli culture had met a violent end. Indications of burning at the top of some high temple mounds suggest that a conflagration had occurred. On the slope of the mountain that ran behind the first Edith Shahr site, a stone circle was found. It measured some thirty feet in diameter with a wall—more than four feet thick—standing some three feet high. The wall was broken in its eastern side by a narrow entrance. Within the circle we found strange, heavy pottery decorated with coarse, appliquéd loops and bands—completely alien to the fine prehistoric pottery of the Kulli culture. This was our first inkling of surprises to come.

DR. FAIRSERVIS, who is a research associate at THE AMERICAN MUSEUM, discovered the Edith Shahr complex, one of the most remarkable finds of this type in the whole Middle East.

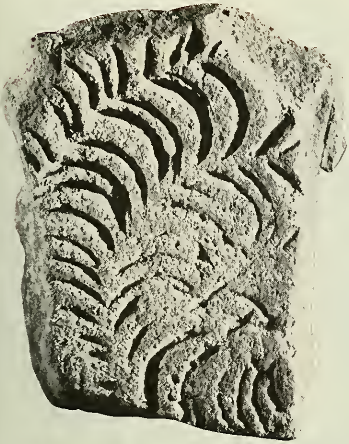
The New Year's eve that we had trekked to the caves had been a difficult one. During our return to camp, night fell and we were forced to walk over rough ground in darkness. Our route led over the back of the mountain whose slopes were behind the first Edith Shahr site. Unable to find a trail, we did considerable stumbling and falling over numerous boulders —a particularly trying hazard. Needless to say, for Dr. and Mrs. Minton and myself, it was a memorable New Year's celebration. It was not until a month later, when I was able to undertake a careful survey of the region in co-operation with the Government of Pakistan's Department of Archeology, that the probable cause of some of our stumbling was revealed. On the mountain slopes that led down to the fertile plains southwest of the first Edith Shahr site was an enormous complex of stone structures through which we had wandered blindly. From the top of the slope overlooking the Porali Valley the remnants of a great stone wall run down the mountainside for more than 2,600 feet. It terminates in the midst of more than 100 structures of different character. Here are stone circles like that previously described. But also there are stone circles made of double rows of white stones, in the midst of which stands a larger stone—like a menhir in Western Europe. There are long "avenues," outlined with white stones, ending in clusters of the same material. These avenues lie along an east-west axis. There are large buildings —square and rectangular—divided into compartments; there are clusters of rectangular structures like those of the Kulli sites. One of these structures is enormous, some 240 feet long.

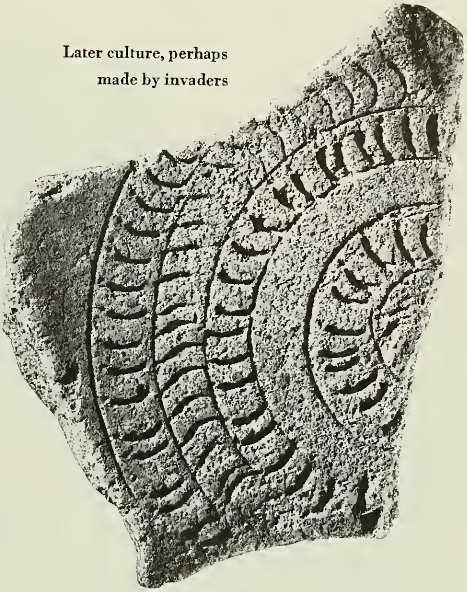
At the time of the discovery I had with me David Henemeier, an Eagle Scout from Karachi. Despite both our efforts, it was impossible to survey this immense complex without help. Even more vexing was the fact that as we worked up the Porali Valley from that point—on either side of the river and close to the Kulli sites—we foun more of these same ruins, with pottery and other artifacts identical t that of the stone circle first encountered. Even after several trips, the discoveries did not end. It was not unti we obtained the use of a helicopter that boon to modern archeology, tha we were able to trace the apparen end of this site (which we call Complex B of Edith Shahr). I say apparent because, on the last day of flight we came across a site with more buildings than any of the others!

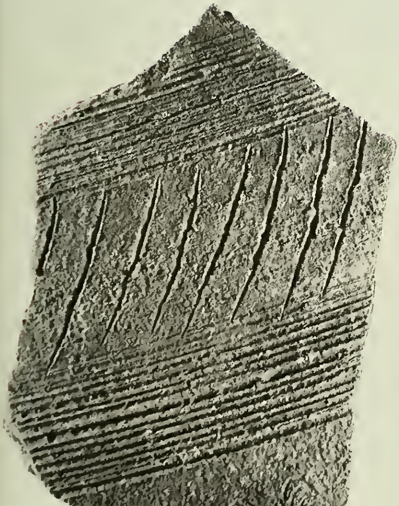
THE true meaning of these finds escapes us for the moment. Ther seems little doubt that they represen an invading group, perhaps related t those groups that created the megalithic structures of South India an Western Iran. These ruins dominat the old Kulli culture sites and over look the entire valley. We found thei traces at the entrance of passes leading east and west. Undeniably the represent a powerful people. But w cannot yet identify these people, n are we at all certain what the Complex B ruins really are. Are they gre ceremonial centers, with solar wo ship the dominant theme? Are the tombs among them, as fragments human bone suggest? Are some them palaces where kings gave orde to a peasant populace spread out the fertile plain?

There are a host of questions an few answers, at least until such tin as our shovels probe the earth and around those ancient walls. F the moment, we are shedding litt light indeed on an extremely important problem in mankind's h tory. But at least there is some ligl

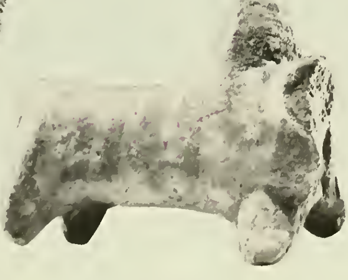
POTTERY ARTIFACTS from early cultu and later period have similar desi motifs. Part of body from model c indicates the use of wheeled vehicl


Early culture pottery

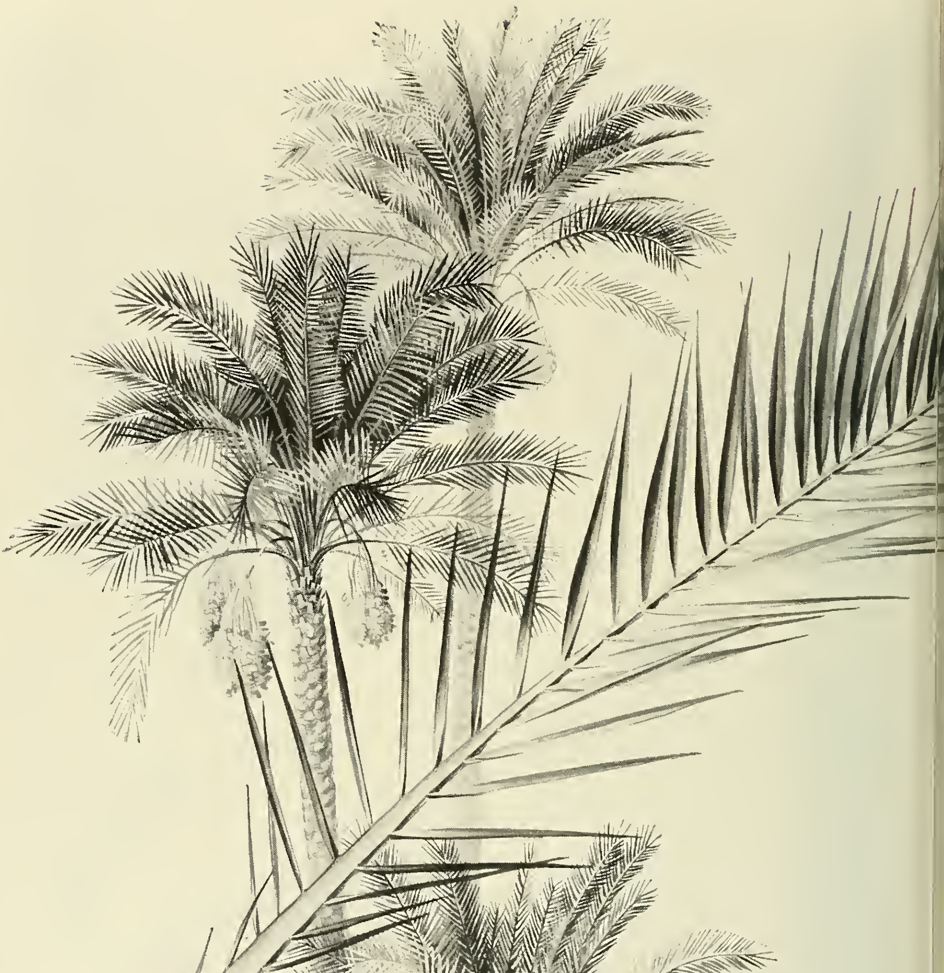

Later culture, perhaps made by invaders


Early culture pottery

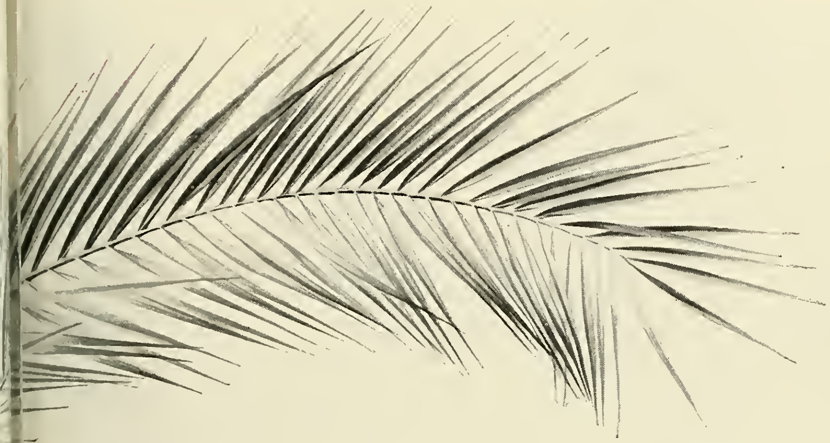
Parts of clay bangles


Brahma bull figurine

Part of a model cart



Date Palm



Speak to the Earth

Modern researchers have identified many Old Testament plants

How did the Holy Land look during the days of Abraham and Moses, Solomon and Isaiah, Ruth and Esther? How did the people live; what did they wear; what was their food? An amazing number of clues can be found in a study of the plants mentioned in the Bible.

The land that gave rise and sustenance to three religions — Judaism, Christianity, and Islam — is only about the size of New Jersey, but the diversity of its landscape is remarkable. To go down to Jericho from Jerusalem, in the rugged Judean mountains, is to drop 3,000 feet in only fifteen miles, moving abruptly from a temperate climate to tropical heat. The River Jordan flows into the Dead Sea at 1,275 feet below sea level, while, at the northern end of the Jordan Valley, the heights of Mt. Hermon and Mt. Lebanon are forever capped with snow. Extending from the borders of the Mediterranean to the foothills of the mountains are three valleys — the Plain of Sharon, the Plain of Esdraelon, and the Valley of Elah. These alone are rich, subtropical areas of agriculture — the "land of milk and honey." The rest of the region is rugged mountain or bleak desert.

This is a land of contrasts. From May to October, the sun beats down without interruption. Streams dry up, and vegetation is sparse, supported only by heavy morning dew. The "early rains" of October and November break the summer drought and soften the land for plowing. In December, January, and February, the rains beat down. The "later rains" of March and April give the crops their last bit of water before the dry season sets in. These diverse geographical and climatic features have produced a corresponding variety of animal and plant life.

In early Biblical times, life was seminomadic, halfway between that of desert Bedouin and settled farmer. We read of Isaac sowing, Joseph binding sheaves, and Reuben in the harvest field. The seminomads gathered olives, dates, walnuts, pistachios, and figs. When they began to form villages and towns, they grew barley, wheat, spelt, millet, sorghum, flax, grapes, apricots, various vegetables, and herbs.

Bread, the staple food, was baked daily; sometimes olive oil was added to the dough.

This article would not have been possible without the help of JOHN ASCH, author and Bible scholar, who has worked broadly in the plant sciences. He has explored for plants for the Hebrew University in Jerusalem, and done research on the Bible flora.

ANNE OPHELIA TODD, whose paintings appear on these pages, is one of the country's leading botanical artists. Before turning to her present specialty, she was an art teacher and a designer of textiles.

Wafers were baked, flavored with honey. Cakes were sprinkled with aromatic herbs. Since water was scarce, goats and sheep provided milk for drinking and for making cheese and butter.

In addition to bread and milk, the ordinary diet consisted mainly of vegetables such as cucumbers, broad beans, leeks, onions, and garlic. There were soups of lentils and beans. On rare occasions, meats were eaten, flavored and preserved by a variety of spices. Standard foods for soldiers, travelers, and field workers were raisins and parched grain.

For dessert there were fruits: fresh and dried figs and grapes, apricots (the "apple" of the Bible), melons, and pomegranates. Pistachios, almonds, and walnuts were relished. Wine was universal: other alcoholic beverages were made from dates and pomegranates. Pomegranates also provided the base for several non-alcoholic drinks, as did the licorice root.

During their wanderings in the wilderness, the Israelites probably lived largely on manna, which, even today, is a favorite confection in many Eastern lands. Manna is a sap or gum exuded from a variety of plants, including alhagi (Sinai manna), tamarisk, flowering ash, Lecanora lichen, and the tiny alga *Nostoc*. It also results from the actions of scale insects, which suck up saps of various plants and then secrete drops of fluid that dry into sticky, sweet-tasting solids on the body of the host plant.

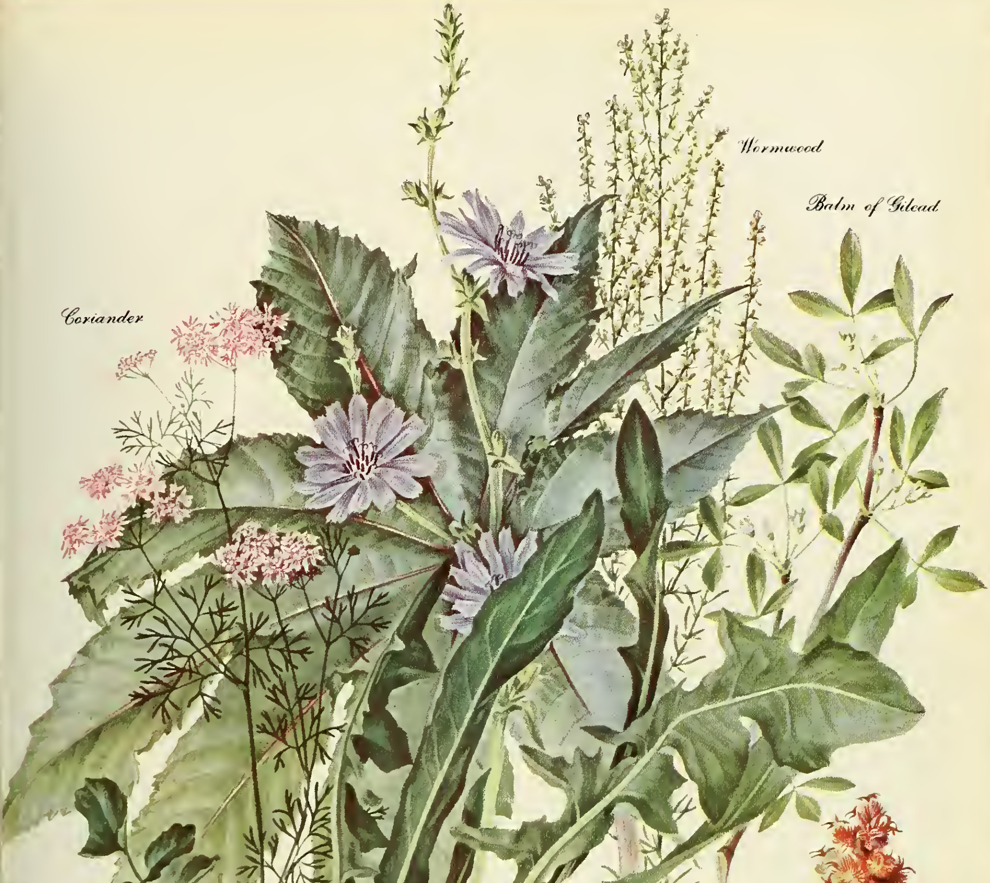
FABRICS of all kinds were also made from plant materials. While some sackcloth was woven from goat hair, other varieties were made from coarse flax, hemp, papyrus, and even from almond stalks. Ordinary linen was used for towels, lamp wicks, nets, sails, and flags. Fine linen made turbans, veils, and undergarments, as well as raiments for royalty and priests. Wool clothing was reserved exclusively for those of wealth. While cotton and silk were used, they were entirely imported – cotton came from Egypt and India, silk was brought from China.

For cooking of all kinds, for drugs, cosmetics, perfumes, and dyes, people of the Biblical lands again turned to herbs and trees. Aromatic coriander leaves, for example, flavored soups and wines, while cumin and coriander seeds made condiments and medicines. The pistils of the saffron crocus seasoned and colored foods and were also used in perfumes and as an important yellow dye. The most common "bitter herbs" were watercress, chicory, dandelion, lettuce, endive, and sorrel. Marjoram was probably the Biblical "hyssop," which served for purification and in cleansing lepers. Perfumery was of particular importance in Biblical times, both for daily use and for ritual functions, and in many cases the same plants were employed in perfumes and medicines. For instance, the rare and costly gum of the Balm of Gilead, a small evergreen tree, was an ingredient of both Wormwood, a name given to several woody plants with a strong aromatic odor, was also used in medicine and perfumery. The "aloes" of the Old Testament were not true aloes; they are thought to have been eaglewood.

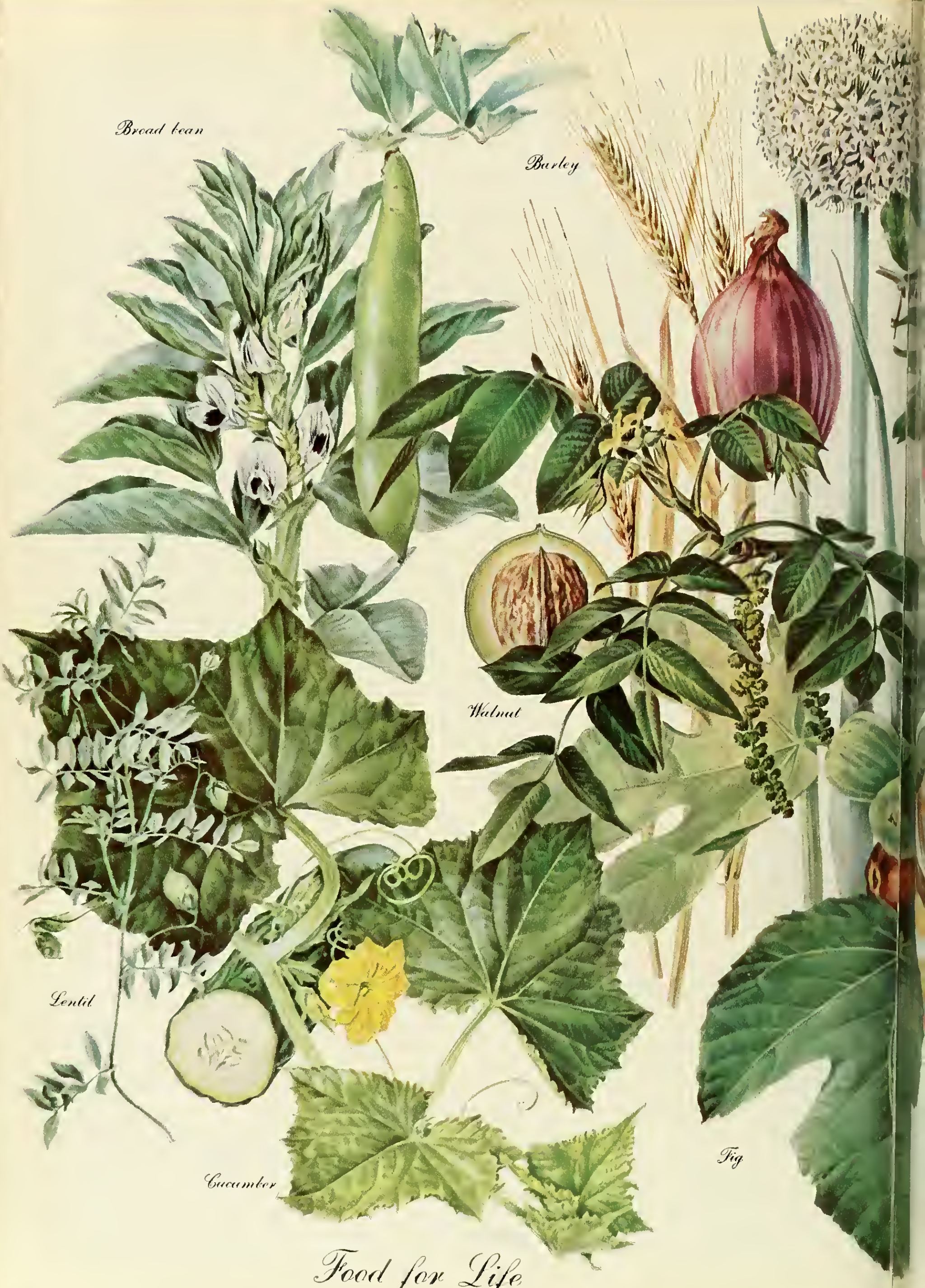
NATURALLY, the Hebrews included local plants and plant products in the incenses and anointing oils used for religious ceremonies. During the Feast of Tabernacles, myrtle and willow branches were braided with palm fronds to form the sacred Lulav, which was held in the right hand during the ritual, while at the same time a citron (the goodly tree), called "Ethrog" ceremonially, was held in the left.

The "cassia" of the Bible refers to two different plants. In Exodus, Proverbs, and Songs, it refers to cassia bark (cinnamon), a common spice and perfume. The ripe fruits of the tree yield oil of cinnamon, one of the ingredients of the holy oil with which officiating priests in the tabernacle were anointed. Another "cassia" is the Indian orris, a thistle-like plant widely used as a Temple perfume and incense.

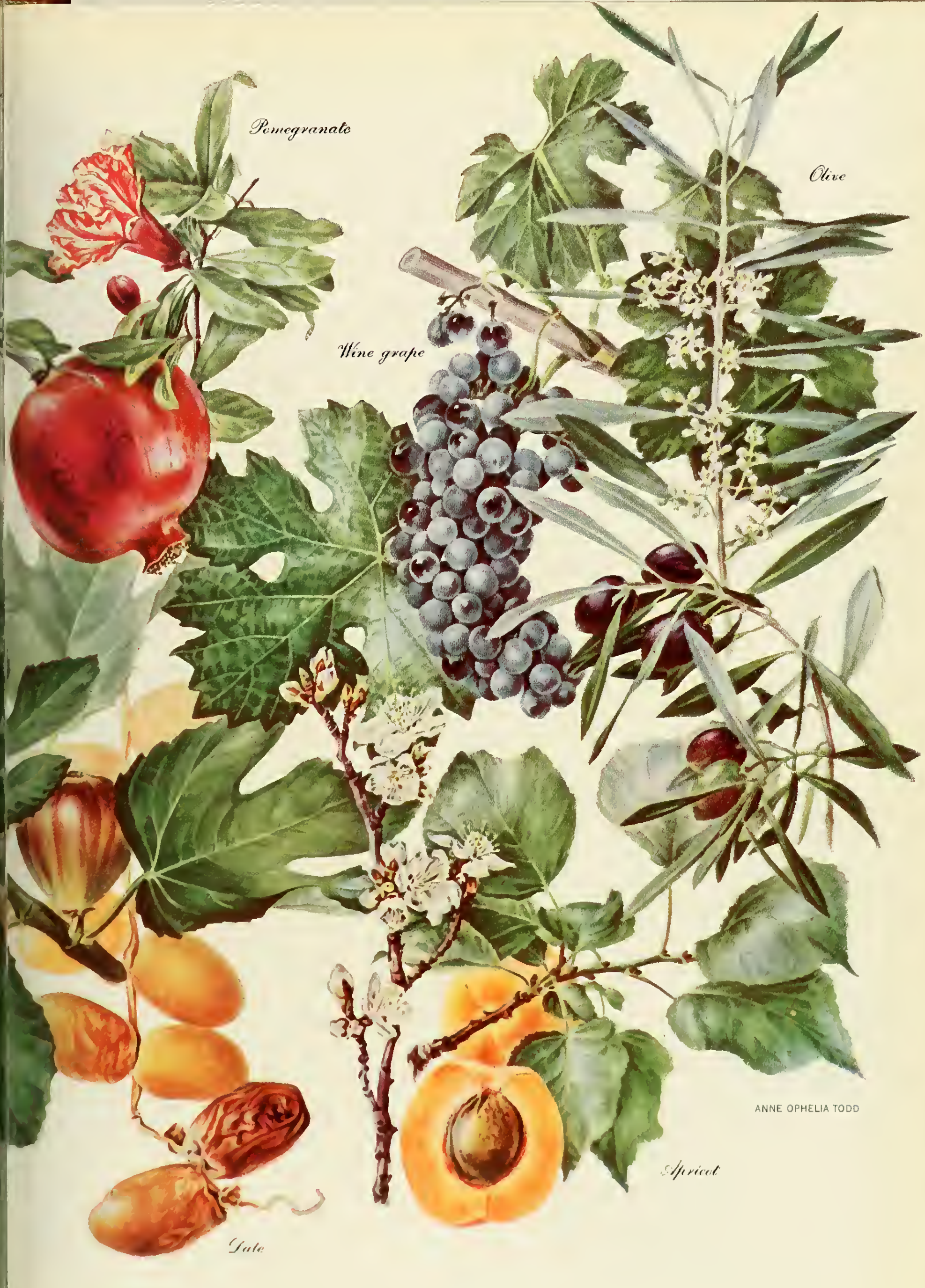
Of all the ceremonial plants, perhaps frankincense and myrrh are the most familiar. The first often came from the tree *Boswellia carterii*, and its bitter, much-sought-after gum was used in the sacrificial services of the tabernacle and Temple. Myrrh is a gum from *Cistus villosus*, a thorny shrub or small tree native to East Africa, whose wood and bark are strongly scented. It was used in embalming, in perfumery, was burned as incense, and – together with aloe, cassia, cinnamon, and olive – was


Wormwood
Balm of Gilead
Coriander
Watercress
Chicory
Castor bean
ANNE OPHELIA TODD

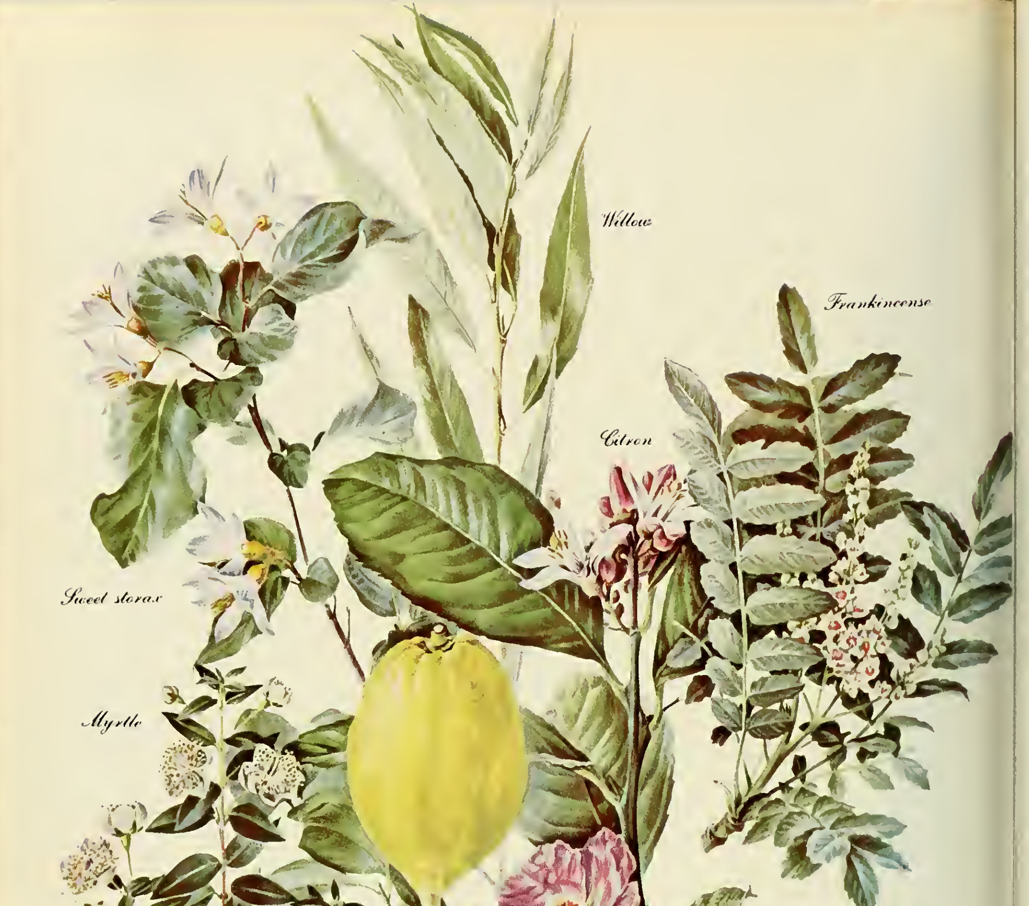
A Garden of Herbs


Broad bean
Barley
Walnut
Lentil
Cucumber
Fig

Food for Life


Pomegranate
Olive
Wine grape
ANNE OPHELIA TODD
Apricot
Date

Fruits of the Land


Willow
Frankincense
Citron
Sweet storax
Myrtle
Myrrh
Cassia
ANNE OPHELIA TODD

Plants for the Temple

an almost indispensable ingredient of holy oil.

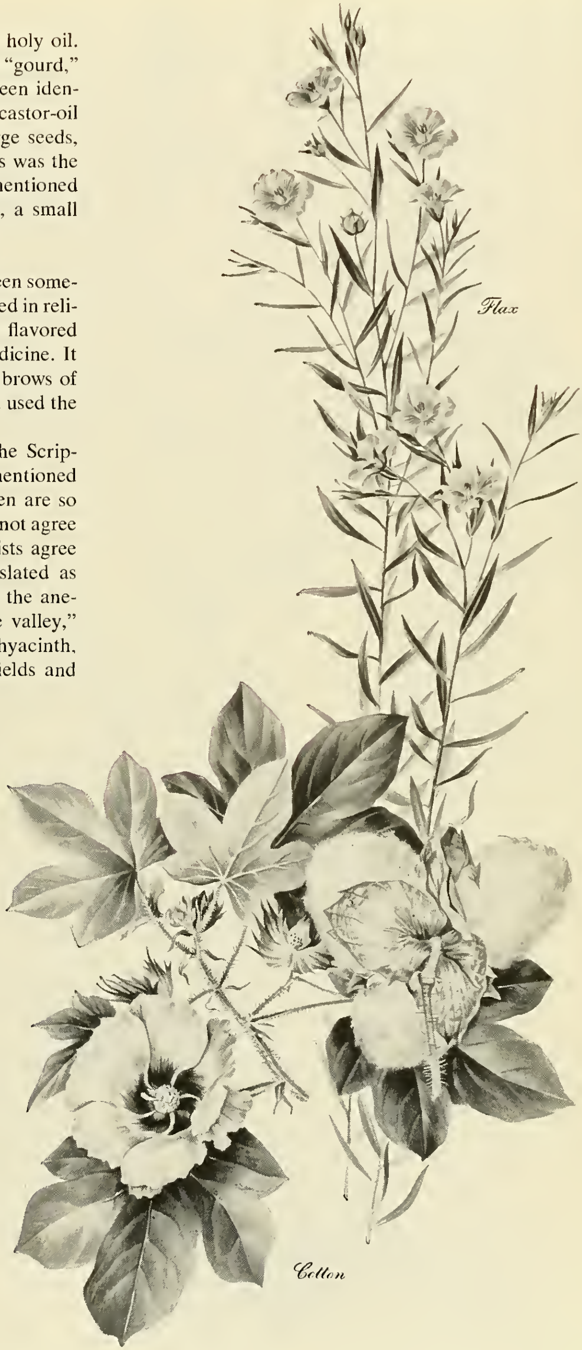
Another oil-yielding plant was the "gourd," mentioned in Jonah 4:6, which has been identified as palma Christi, the common castor-oil plant. The oil, obtained from the large seeds, was used extensively in ceremonies, as was the highly perfumed gum of the "stacte," mentioned in Exodus. Stacte is the sweet storax, a small tree with beautiful, aromatic flowers.

The bay tree, or laurel – an evergreen sometimes called sweet bay – also figured in religious ceremony. Its aromatic leaves flavored foods, its roots and bark supplied medicine. It was a mark of triumph, adorning the brows of priests, poets, and victors, while David used the laurel as a symbol of prosperity.

References to flowers abound in the Scriptures. Unfortunately, many are not mentioned by name, and some of the names given are so vague that translators and botanists do not agree on their identities. Today most botanists agree that the Hebrew *Shushan,* once translated as "lily," or "lilies of the field," refers to the anemone or windflower. The "lily of the valley," on the other hand, is believed to be the hyacinth, whose blue blossoms brighten both fields and rocky places. Another "lily" is the iris, or yellow flag, that grows in shallow waters on the margins of ponds and streams, sometimes in extensive masses.

The "rose" of the Bible is thought to be the narcissus in some passages, and the oleander in others, but the "rose of Sharon" refers to the tulip. "Dove's dung" is the star-of-Bethlehem – a spring-flowering plant whose bulbs served as food during times of drought and starvation. "Tirzah," in Song of Solomon 6:4, is acknowledged to be the crocus.

The grapevine is the first cultivated plant mentioned in the Bible: indeed, there are more references to vine-growing and wine than to any other plant or plant product. Grapes supplied fresh fruit, raisins, a sweet syrup known as "dibs," and vinegar, as well as the alcoholic beverage. There are many laws in the



Old Testament relating to the selection, planting, care, harvesting, pressing, storing, and tithing of vines, grapes, and wine.

Trees, many of which were venerated as sacred, played important roles in the lives of people of the Holy Land. There is a great deal of controversy over the hundreds of tree references in the Bible, and the identities of the evergreens – especially fir, pine, cypress, juniper, and cedar – are in doubt.

The cedar of Lebanon is one of the most sacred of Bible trees. Chief among the evergreens, it was known as the "Prince of Trees" – a symbol of grandeur, might, majesty, and dignity. Many Lebanon cedars are over 2,000 years old. Their wood is so rot-resistant that they were cut in great quantities to construct Solomon's "House of Cedar" and the Temple. The great cypress forests of Biblical days were called "gopher-wood" groves. Because of its durability, cypress was used to build idols and ships–it may have furnished Noah with wood from which he constructed his ark.

The very word Palestine means "land of palms." All manner of foods, beverages, confections, ornaments, fuel, household utensils, clothing, footwear, and cordage were supplied by the flowers, fruit, seeds, fronds, and trunk of the palm. For the Hebrews, the palm was a token of triumph, carried in processions. Indeed, the Israelites' palm festival preceded today's Christian Palm Sunday.

As important as the palm, economically and religiously, was the olive tree – a symbol of peace. Its gnarled trunk and spreading, silver-green foliage remain characteristic features of the Mediterranean landscape. Moses called the Land of Canaan a "land of olive oil." In addition to food, the olive supplied illuminating oil, and was used in soaps, cosmetics, and medicine. It was a constituent of the holy oil used for anointing royalty and for Temple ceremonies, and its beautiful, hard wood decorated the doors of the Temple.

The almond is the first tree to flower in the Holy Land, and is in full bloom in January. *Shaked*, the Hebrew word for almond, means "hasty awakening." This is dramatized in the story of Aaron's rod, which in a single day burst into bloom and yielded almonds as a sign of the fulfillment of God's promise. Oil, ointments, and cosmetics were made from the nut, as was a favorite food flavoring.

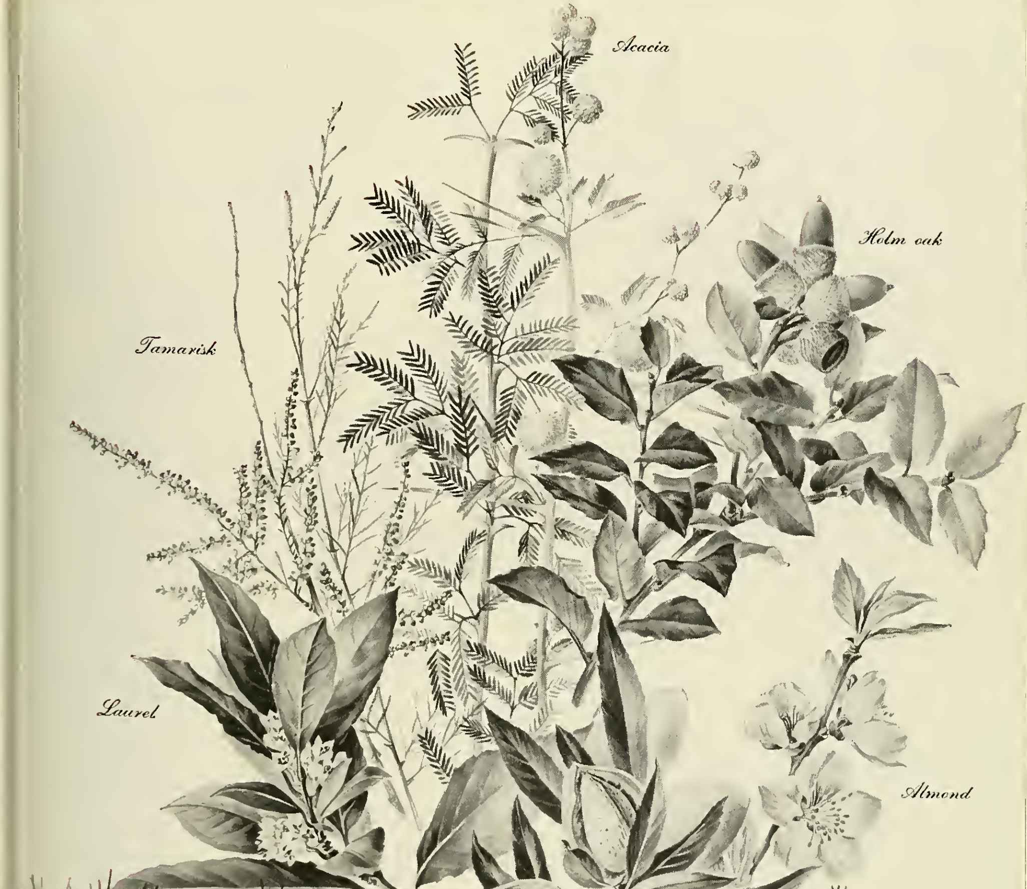
Of all tree fruits, the acorn may have been the first gathered by man. Forests of various species of oaks once covered the hills and mountains of the Holy Land, and many of the events of Hebrew legend and history occurred beneath oak trees. Oak worship was firmly established among the pre-Israelites of Canaan. The oak is still considered the "King of the Forest," an emblem of majesty and strength.

The tamarisk and acacia also figure prominently in the Bible. The tamarisk, a small tree, grows in barren, sandy areas where its shade is greatly appreciated. In spring it bears spikes of beautiful blossoms that envelop the whole tree. The acacias, with their aromatic, long-lasting wood, are among the most beautiful, fragrant, and useful of plants. Exodus 27:1 says, "Thou shalt make an altar of shittim wood . . . ," and the reference is to acacia, credited in the Bible as material for the Ark of the Covenant and the Altar of the Tabernacle. Gum arabic, derived from these trees, was an important article of commerce, used in many industries. The yellow flowers were employed in perfumery; the pods yielded feed and food; from the chips of the heartwood came the drug catechu, and the bark was used to tan leather.

One of the four "Sacred Species" of the Feast of Tabernacles is the myrtle–an aromatic evergreen shrub or tree–that adorned huts or booths during this festival. Its dark, glossy, sweet-smelling leaves, its white or pink, perfumed flowers, and its bluish-black, aromatic berries were dried for condiments and perfumes. In the Bible, myrtle is regarded as a symbol of divine generosity, peace, and justice.

The "sycamore," mentioned several times in the Bible, is really the sycamore fig, a tall evergreen with aromatic leaves and fruit that is small, spotted, and not particularly tasty.

The common fig, one of the most important of all Bible plants, is the first tree mentioned by name: " . . . and they sewed fig leaves together and made themselves aprons" (Genesis 3:7). The fig tree grows everywhere in the Middle East – among rock crevices, in old walls, and along terraces. Besides fruit for food, the small, spreading tree provided welcome shade and was a symbol of tranquility. Indeed, there is scarcely a better way in which to end this inventory of Biblical plants than to cite I Kings 4:25: ". . . and Judah and Israel dwelt safely, every man under his vine and under his fig tree.


Acacia
Holm oak
Tamarisk
Laurel
Almond
Cedar of Lebanon
Cypress

Trees of the Lord

ANNE OPHELIA TODD

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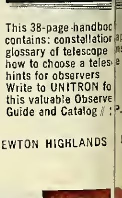

This 38-page handboo
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SKY REPORTER

he telescope, Galileo, and the origins of optical astronomy

By SIMONE DARO GOSSNER

N ASTRONOMICAL MATTERS, the seventeenth century had begun most auspiciously with Kepler's discovery of the ws of planetary motions. Almost simultaneously, the in- ntion of a new instrument was destined to furnish imme- ate proof of the validity of heliocentric theories.

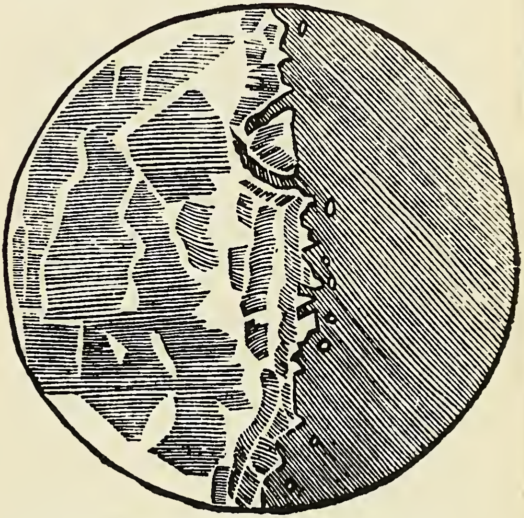
The origin of the telescope is shrouded in mystery. If two mple lenses are aligned in a certain manner in the line of ght, they enable one to view distant objects more clearly. is possible, as one account tells it, that this property was scovered accidentally (*ca.* 1608) in the shop of a Dutch ectacle-maker. Yet, crude combinations of lenses and irrors seem to have been designed—in theory if not ma- rially—in the latter part of the sixteenth century. In any se, the great Galileo (1564-1642) was among the first tronomers to grasp the potential of the instrument for serving the heavens, and to adapt it for this purpose.

Only two months elapsed from the day Galileo com- eted a telescope that satisfied him—his fourth—to the blication of his pamphlet *Sidereus Nuncius* (Sidereal essenger) on March 10, 1610; but in those two months learned more about the universe than had ever been sur- ised since the dawn of mankind. The priority of some of s discoveries was a matter of dispute almost from the rt because the astronomical use of telescopes had spread pidly. Historians of science are still arguing the point. It a testimony to his genius, however, that Galileo did not nit himself to a mere recording of observations, but that was able to sense their implications at once and to ana- ze them with faultless logic.

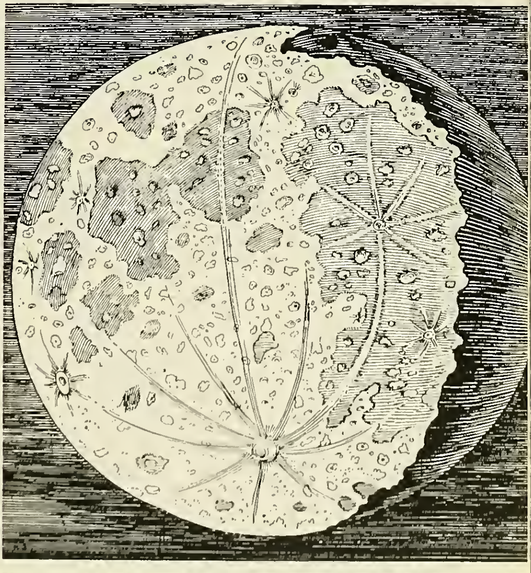
HE first telescopic discoveries had a shattering impact on prevailing cosmological concepts: gone was the or- rly world in which planets were wandering pinpoints of ht against a background of a few thousand stars, and in ich the sun was a perfect orb of pure fire. All of a sud- n, the moon stood revealed as a rugged body with a untainous surface, its peaks casting long shadows. untless stars and nebulous objects appeared where only pty space had been seen before. Planets acquired visible ks. Venus and Mercury showed phases like the moon's. piter turned out to have not one but four moons (al- ough no one would believe this at first); Saturn sported t quite definable but certainly peculiar appendages; and orror—those spots crossing the sun were actually blem- es on what should be a perfect surface.

The phases of Venus and Mercury were immediately ognized by Galileo as proof that those planets revolve und the sun. The Ptolemaic system assumed that they nained always between the sun and the earth. If this re so, a telescope would show them at all times in a cres- it phase; on the contrary, they were found to exhibit al- nating crescent and gibbous phases, a phenomenon that ıld be explained only by assuming that their distance m earth is alternately smaller and greater than the 's (see illustration on p. 43, upper right).

The telescopic discovery of Jupiter's four principal sat-



GALILEO drew the moon he saw through his telescope for his book *Sidereus Nuncius*, first published in Venice in 1610.



HIRZGARTER'S 1613 moon drawing is still crude, but main features, such as the ray structure of craters, are visible.

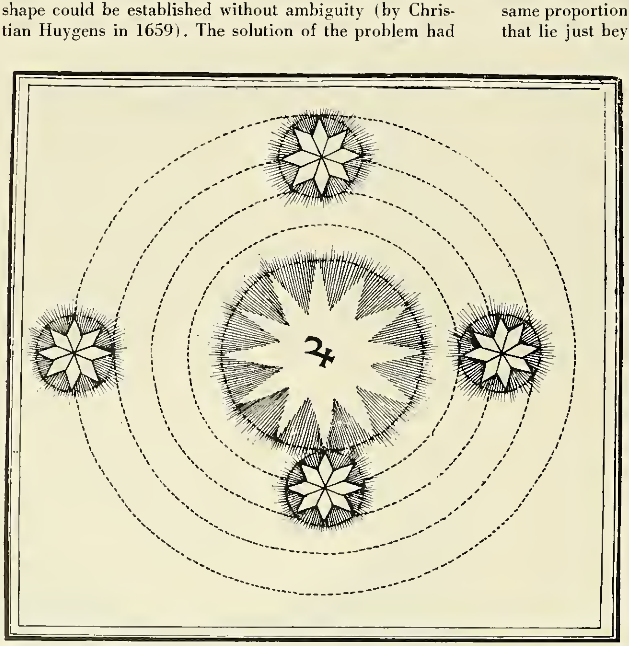
ellites removed a serious obstacle to the acceptance of Copernican theories. Until then, even those scientists who were favorably disposed toward the heliocentric view considered it illogical that the moon alone should revolve around the earth whereas all other planetary bodies moved around the sun. Jupiter's satellites served to prove that this occurrence is not unique in the solar system. At first, however, news of their discovery was received with utmost incredulity in all quarters. Disciples of Aristotle, who were still numerous at that time, refused to believe in their existence on the grounds that Aristotle had never mentioned them. Kepler himself, when he first heard of it, found it hard to accept the fact that Jupiter should have four moons when the earth—this eminent abode of life—has only one; a few months later, however, he was able to observe them through his own newly acquired telescope.

Features of the lunar surface were among the most readily accessible to a primitive telescope. Accustomed as we are to photographic observations, we may be startled by the crudeness of Galileo's early drawings (see page 41, top), but it is a fact worth noting that he was able to derive the approximate height of lunar mountains from the pattern of light and shadow on the moon's surface.

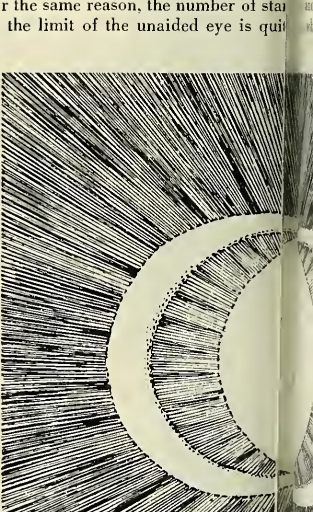
THE rings of Saturn were almost at the limit of the power of Galileo's instrument. His contemporary, Christoph Scheiner, S.J., saw them in the form of two lobes projecting on either side of the planet, but Galileo attributed this effect to inferior optics in Scheiner's telescope and maintained that they were two motionless companions of Saturn. Half a century elapsed before their true shape could be established without ambiguity (by Christian Huygens in 1659). The solution of the problem had been retarded further by an extraneous circumstance. The rings are extremely thin and the tilt of their plane to our line of sight varies from year to year. When they are seen edge-on, they almost vanish from view and even powerful telescopes could not reveal their shape. Although Huygens possessed a suitable instrument as early as 1655, the position of the rings at that time was most unfavorable, and only in subsequent observations did he gradually discover that they were circular in nature.

Under favorable conditions, sunspots may be seen with the naked eye. They had been observed on many occasions in pretelescopic times, but invariably they had been attributed to external causes: planets in transit across the sun's disk, distant birds in flight. Sustained telescopic observations revealed that the spots are of varying size, that some are short-lived whereas others persist for over a month and that all share a common motion across the solar surface. After much soul-searching, Galileo decided that they are features of the sun. He concluded that the latter i rotating on an axis and that its spots share that rotation. I is not surprising that Galileo should have been so reluctan to propose this interpretation. The idea of a blemished su ran afoul of all philosophical concepts concerning its nature: but, as telescopes improved and observations accumulated, his conclusions became indisputable.

On the average, stars appear fainter when they are farther away; therefore, every time the power of a telescop is increased to reach fainter stars, a larger volume of spac comes under scrutiny. Since the volume of a sphere increases as the cube of its radius, the number of fainte stars that become observable increases in essentially th same proportion. For the same reason, the number of star that lie just beyond the limit of the unaided eye is quit

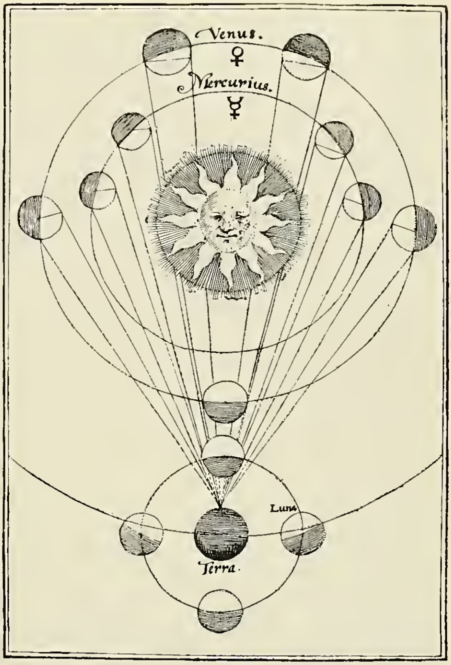


JUPITER and the schematized orbits of its four principal satellites, as first discovered by Galileo, were published by M. Hirzgarter in *Detectio Dioptrica.*

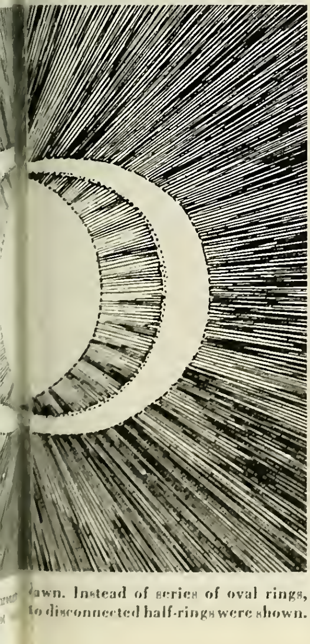


SATURN's rings, as viewed through 1 century telescope, were not correc arge. As soon as Galileo directed his modest telescope oward the Milky Way, he discovered thousands of new tars. The implications of this fact were not grasped immeliately; this may be the reason why his description of rich tar fields in Orion and the Pleiades evinced few reactions rom his contemporaries. A few decades later, however, ne of his followers expressed—rather timidly—the opinon that stars of greatly different brightness must lie also t greatly different distances. Thus the first hole was puncured in Ptolemy's "eighth sphere," the sphere of fixed tars that was believed to form the boundary of the solar ystem, and the existence of which no one had ever had eason to question until then.

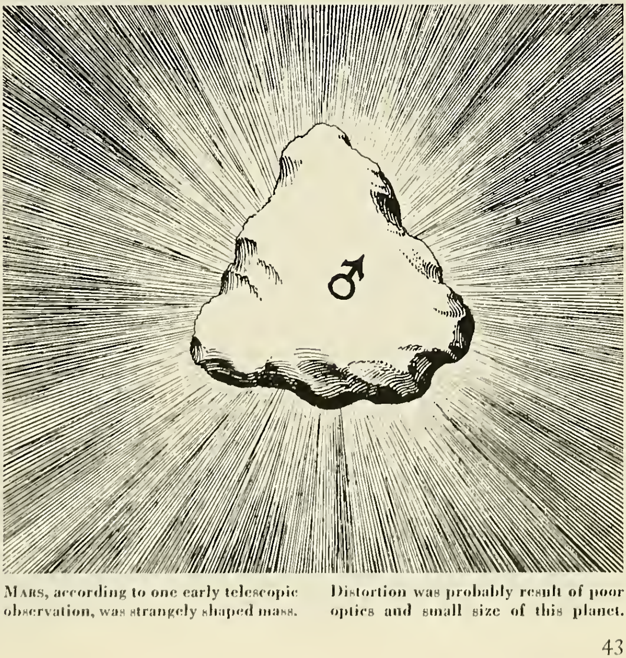
THE most remarkable feature of these early telescopic discoveries is that they could be accomplished with uch imperfect instruments. Glass was of poor quality; ens-grinding techniques were primitive; and the distorted nages produced by simple lens systems were sometimes nrecognizable. The observer had to draw, mostly from emory, what he saw through the eyepiece, and the jourey from the astronomer's sketchbook to the printer's enraving certainly did not add to the accuracy of published esults. As a case in point, we show on this page (below, ight) what may well be the most startling picture of the lanet Mars in all astronomical literature. It appears in a amphlet entitled *Detectio Dioptrica,* published in 1643 by e Zurich mathematician Matthias Hirzgarter. In defense f the Copernican system, the author presents the latest bservations of an unnamed "Neapolitan gentleman" who ad sent them to him "through a trusted friend in Padua." he anonymous Neapolitan was probably Francisco Fonna, who claimed to have modified the Galilean telescope.



Mercury and Venus have phases like the moon's, as shown in 1643 drawing. Sun is at center, earth and moon below.



awn. Instead of series of oval rings, to disconnected half-rings were shown.



Mars, according to one early telescopic observation, was strangely shaped mass. Distortion was probably result of poor optics and small size of this planet.

THE SKY IN JUNE AND JULY

From the Almanac:

Last Quarter	June 5, 4:19 P.M., EST
New Moon	June 13, 12:17 A.M., EST
First Quarter	June 21, 4:02 A.M., EST
Full Moon	June 28, 7:38 A.M., EST
Last Quarter	July 4, 10:33 P.M., EST
New Moon	July 12, 2:12 P.M., EST
First Quarter	July 20, 6:14 P.M., EST
Full Moon	July 27, 2:51 P.M., EST

The summer solstice will occur on June 21 at 10:30 A.M., EST. On that date, the sun will reach the northernmost point of its annual course and summer will begin in the Northern Hemisphere. On July 5, the earth will be at aphelion, the point of its orbit farthest from the sun.

For the visual observer:

Mercury, at its greatest eastern elongation on May 31, will be visible near the western horizon, shortly after sunset, during the early part of June. It will set about one and three quarter hours after the sun on June 1, one hour after the sun on June 15. For the remainder of June and early July, the planet will be too close to the sun for observation because of its inferior conjunction with that body on June 27. It will rise an hour and a half before the sun in mid-July, one hour before the sun on July 31. It may be seen, very low in the east before sunrise, for several days previous to and following July 19, the date on which it reaches its greatest western elongation.

Venus will rise in the northeast at 2:30 A.M., local standard time, on June 1, 2:15 A.M. on June 15, 2:00 A.M. on July 1, 1:45 A.M. on July 15 and 31. A conspicuous object in the eastern sky at sunrise, its brightness will fade slightly from —4.1 magnitude on June 1 to —3.6 on July 31. It will pass south of the Pleiades in the early part of July.

Mars, in the evening sky (+1.8 magnitude), will set at 11:30 P.M. on June 1, 11:00 P.M. on June 15, 10:30 P.M. on July 1, 9:45 P.M. on July 15, 9:00 P.M. on July 31. Although it is in Leo for most of this period, it will pass near Regulus at the end of June.

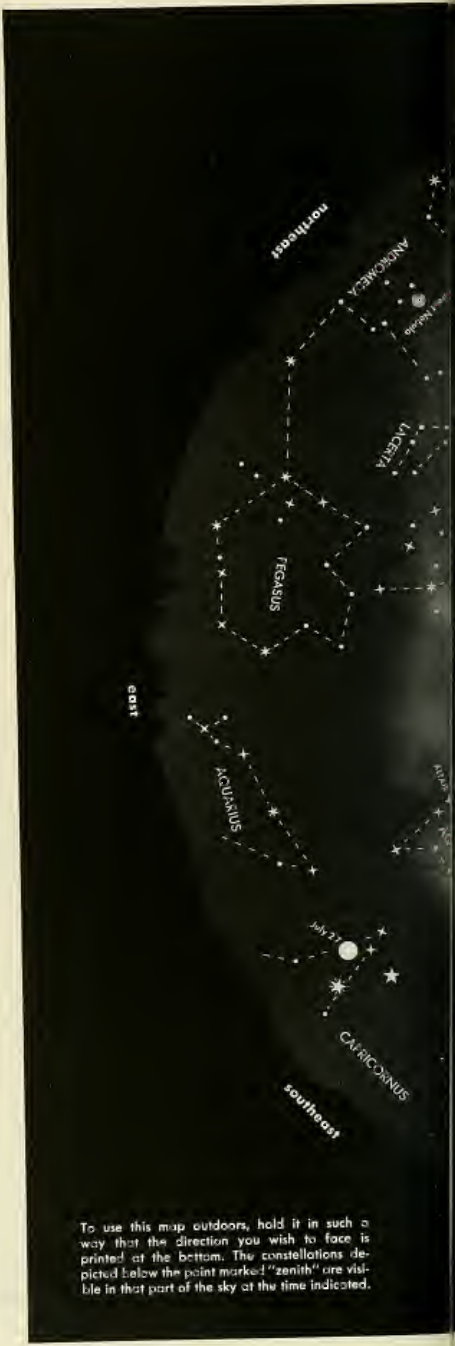
Jupiter, in Capricornus (—2.2 magnitude), will rise in the southeast at 11:00 P.M. on June 1, 10:00 P.M. on June 15, 9:00 P.M. on July 1, 8:00 P.M. on July 15, before sunset on July 31. It will remain visible for the rest of the night throughout that period, except toward the end of July, at which time it will set in the southwest approximately 30 minutes before sunrise. It will be at opposition (on the meridian at midnight) on July 25.

Saturn, in Sagittarius (+0.4 magnitude), will rise about half an hour before Jupiter during both months and will be at opposition on July 19. It will remain visible for the rest of the night in June and early July but will set about an hour before sunrise by July 31.

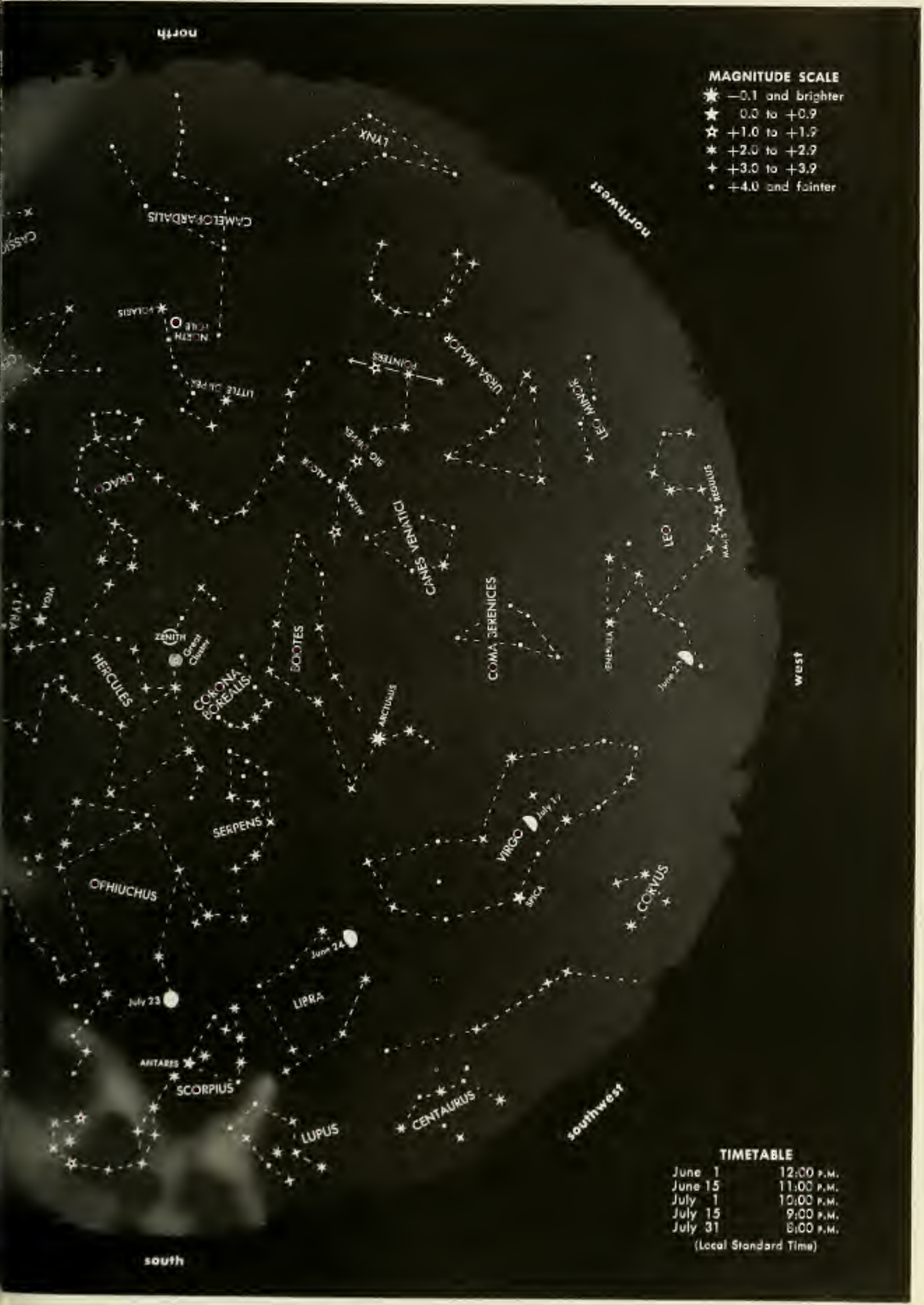
Meteor Showers:

The Delta Aquarids may be expected on July 29. Normal maximum for this shower is twenty meteors per hour as seen by a single observer. However, the moon will be two days past full on that date and will interfere with observations. A few Perseids—presaging August showers—may begin to appear in the early morning at the end of July.

On the preceding pages, MRS. GOSSNER offers the sixth in her 1961 series on the growth of cosmological concepts.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.

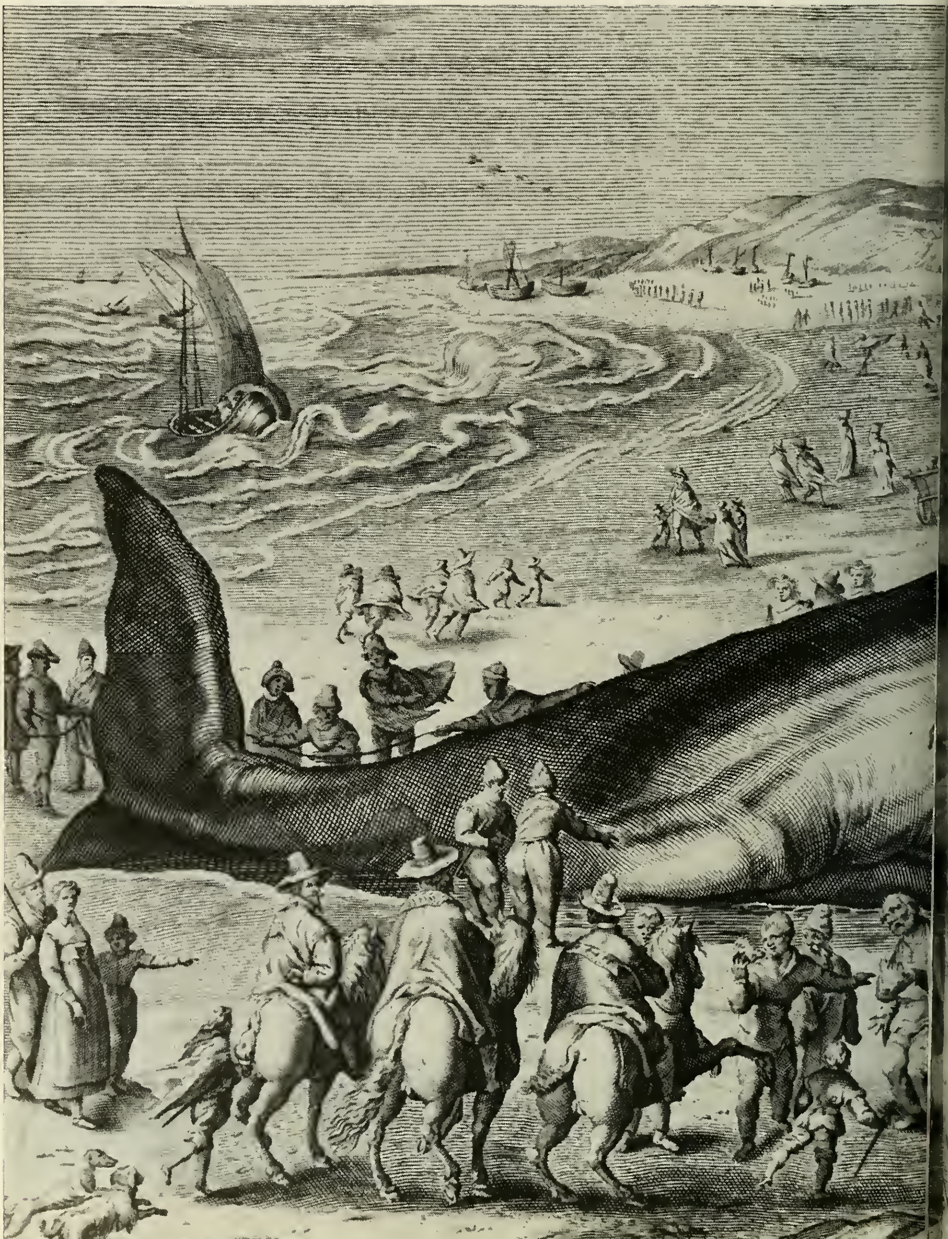

north
MAGNITUDE SCALE
−0.1 and brighter
0.0 to +0.9
+1.0 to +1.9
+2.0 to +2.9
+3.0 to +3.9
+4.0 and fainter
LYNX
northwest
CAMELOPARDALIS
CASSIO
POLARIS
NORTH POLE
LITTLE DIPPER
POINTERS
URSA MAJOR
LEO MINOR
BIG DIPPER
ALCOR
MIZAR
DRACO
CANES VENATICI
LEO
REGULUS
MARS
COMA BERENICES
DENEBOLA
June 24
west
LYRA
VEGA
ZENITH
Great Cluster
HERCULES
CORONA BOREALIS
BOOTES
ARCTURUS
VIRGO
July 1
SPICA
SERPENS
OPHIUCHUS
CORVUS
June 24
LIBRA
July 23
ANTARES
SCORPIUS
LUPUS
CENTAURUS
southwest
south

TIMETABLE

June 1	12:00 P.M.
June 15	11:00 P.M.
July 1	10:00 P.M.
July 15	9:00 P.M.
July 31	8:00 P.M.

(Local Standard Time)

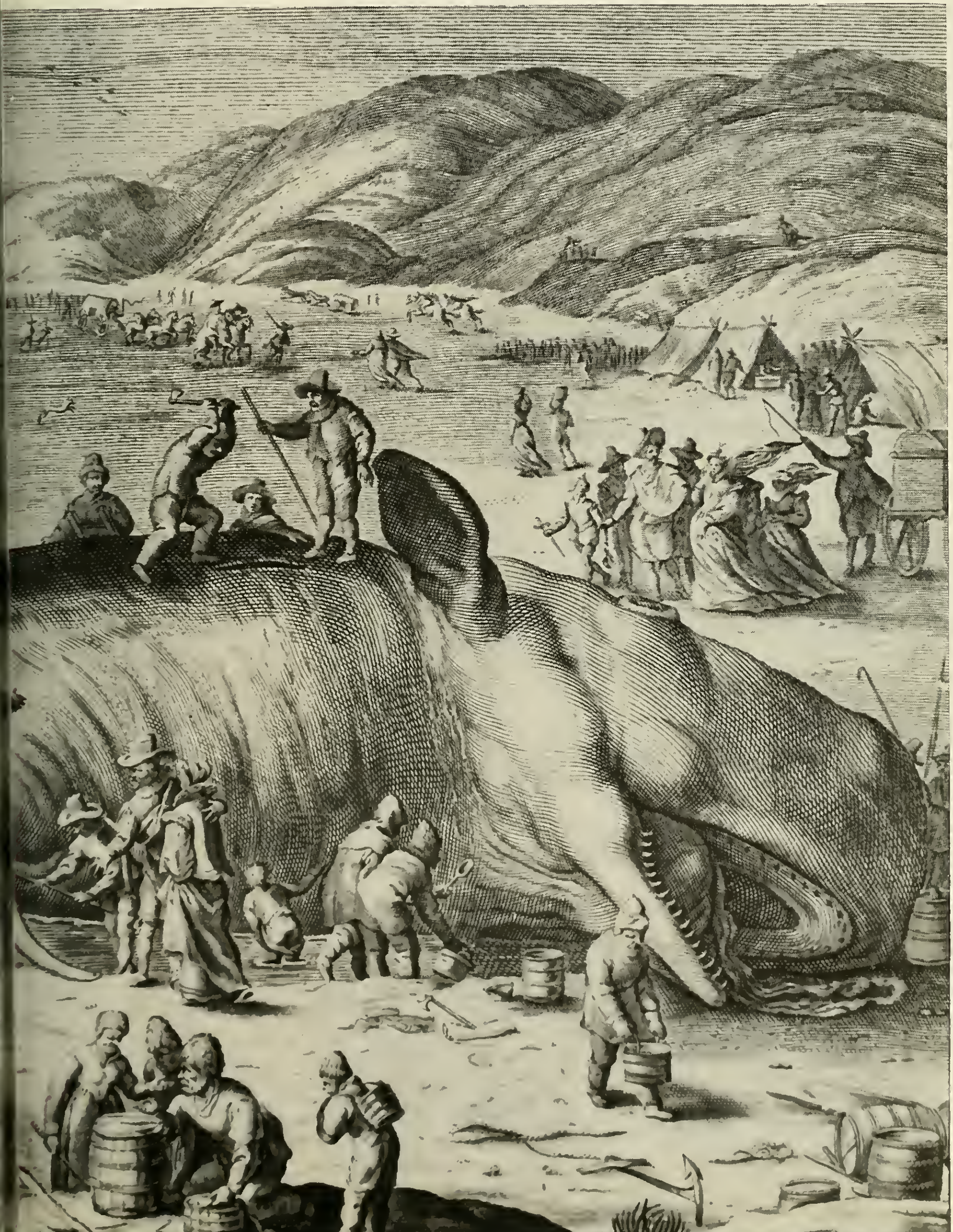
A Question in Whale



Behavior

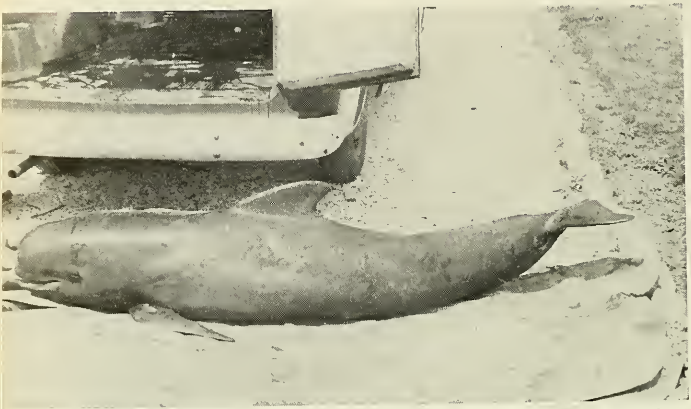
Most solitary strandings seem to be in response to sickness

By Carleton Ray



Common dolphin, stranded on beach at Staten Island, New York, seemed to be in good condition when found, later proved to be suffering from pneumonia.

Harbor porpoise, captured in a fish weir in New Brunswick, died on way to Aquarium. Autopsy revealed no cause of death, which may have been fright.



Pilot whale calf, which had lost its mother, was stranded in shallow water on Long Island. It was captured by a fisherman, who seized it by the tail.

WHALES—some of them gigantic almost beyond comprehension —bring to mind the awesome, powerful, and mysterious. Today, we even suspect that they are as intelligent as any mammal but the primates. These "reconstructed" land animals, reversions to a life in the sea, occasionally return again to land. The reasons whales do this—stranding themselves, usually to die—are the subject of investigation of this article. At the New York Aquarium, we have had first-hand experience with strandings of two species of the smaller whales, and two species of their relatives, the porpoises and dolphins.

The feelings of most people who encounter a large whale stranded on a beach have been summed up by the Dutch artist who in 1598 made the delightful copper engraving shown on pp. 46-47. This is a male sperm whale (Moby Dick was one), the source of spermaceti, sperm oil, and ambergris. A champion diver, it goes down a half-mile or more in search of the formidable giant squid—its favorite food.

Who can help but be excited when he finds one of these giants on a beach! Sometimes the animals are stranded alive. As the whale struggles in the ebb tide, it only manages to dig itself deeper into the sand. Its expressionless mouth may occasionally gape, or a rush of air may issue through the blowhole on top of the head. As the ebbing water deserts the body, the creature's weight becomes its own worst enemy, bearing down upon the chest, eventually causing suffocation.

The words "whale," "dolphin," and "porpoise" need not confuse one as applied to those mammals which, together, make up the order Cetacea. Scientifically, the cetaceans are divided into two suborders: one is composed of toothed animals and th other of those that have baleen o whalebone—an epidermal derivativ that is homologous to hair or nails—instead of teeth.

SPECIES of the latter suborder the Mysticeti, feed on plankto strained from the sea through th whalebone that hangs from the upper jaws. All the mysticetes a large, so all qualify as whales. The range in size from the pygmy rig whale, *Neobalaena marginata* (leng to 20 feet), to the largest animal th ever lived, the blue whale, *Balaeno tera musculus*, that reaches lengths ver 100 feet and weights of more than 20 tons. There are few kinds of myicetes—a few species of rorquals including the blue, finback. piked nd sei whales), gray whales, humpacks. right whales and bowheads.

The toothed cetaceans — suborder dontoceti—include some whales, but s membership is primarily composed porpoises and dolphins. The odoncetes are a large group, comprising veral families of several dozen spees. Which of them is called whale, nd which dolphin or porpoise, is nerally clear if one but mildly conders its zoological relationships. The ly really huge, toothed cetacean is e afore-mentioned sperm whale, *Phyter catodon*, males of which occaonally grow to more than 60 feet in ngth. The female is about half the ze of the male. The odd and rare aked whales of the genera *Mesoplon, Ziphius, Hyperoodon,* and *Berdius* grow to moderate size, mostly om 15 to 30 feet. *Berardius* is the rgest, reaching over 40 feet.

Fortunately, the smallest cetaceans at we commonly call whales all fall o small, special families: the white ale or beluga. *Delphinapterus leus*. and the strangely armed narwhal, *onodon monoceras*, together constie the family Monodontidae. The gmy sperm whale, *Kogia breviceps*, a diminutive member, and the only ier living member, of the family to ich Moby Dick belonged, the Phyeridae. All three of these little ales mature at close to ten feet in gth, but their zoological peculiarity lps even the layman to distinguish m as "whales" from the dolphins d porpoises.

The family Delphinidae, largest of cetacean families. includes some ecies large enough usually to be led whales. The male killer whale, *cinus*. grows to thirty feet. while the gest male pilot whale. *Globicephala*, nearly that large. We call small mbers of this family dolphins. but members have in common their ne-shaped teeth. The best-known are common dolphin, *Delphinus dels*, and the bottle-nosed dolphin, *Trsiops truncatus*.

The porpoise family, Phocaenidae, turn. all have spade-shaped teeth l are all small. Best-known is the bor porpoise, *Phocaena phocaena* large male is scarcely six feet long). handsomer and smaller porpoise he Dall's porpoise, *Phocaena dalli*. This is one of the smallest of cetaceans, reaching a mere five feet. Here we are concerned with four species by these definitions: two species of whale, a porpoise, and a dolphin that were stranded or trapped in shallow waters. All but the porpoise, which died en route, were brought alive to the New York Aquarium for observation.

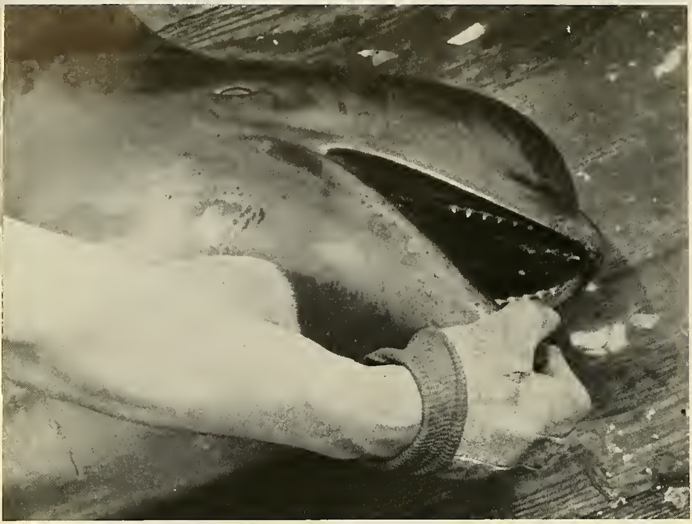
How do whales and their relatives live their highly specialized lives? Marine mammalogists are just beginning to learn some answers to this question. Quite a bit is known of cetacean anatomy, less of behavior, and of the way in which they use sound in their delicate underwater navigation. We have scattered information on birth, migration, and death. But as yet we are in possession of only fragments of the total life picture.

One way of learning more is to take every advantage of the fact that some whales are stranded alive. Such delicate measurements as electrocardiagrams have been taken under these circumstances. Dead, stranded animals may be measured, and some of their organs preserved. Every so often it is possible to bring a stranded animal back to captivity, where it can be observed over a period of time. What we discover in such cases may be only a slight beginning of knowledge, and as we shall see, most of it is knowledge about sick animals. Nevertheless, sickness is a part of life, too, and this information may prove to be more important than we now can determine. Finally, small whales and their smaller relatives are presently being kept successfully in captivity. A third generation bottle-nosed dolphin is now thriving in Marine Studios, Florida, never having seen the sea at all!

On land, body weight pressing on the lungs can cause a whale to suffocate.

No one can guess how many cetaceans are stranded annually through-

Ten-foot beluga from Prince Edward Island, trucked to Aquarium in a large wooden tub, was partially covered with water and cushioned with burlap bags.



Sharp, pointed teeth are typical of the pilot whale. Parallel lines of dots visible on the lower jaw may have been made by tentacles of octopus or squid.

Teething porpoise, only a few month old, shows tooth development, whic

out the world, although scientists, particularly in England, have for years kept records of reported strandings. In the last three years, we have observed five pilot whale strandings on Long Island and New Jersey shores alone, and surely this is far from a total count for this species for even one short length of the Atlantic coast. Why are cetaceans thus stranded? This is a question to which we are beginning to get an inkling of an answer. First, strandings of a single animal are one thing: they occur quite frequently. Mass strandings, involving whole groups or schools of cetaceans, are quite another matter.

Several expressions are used to describe one theory as to why schools of some whales, particularly the pilot whales, come ashore. "Mass mania" is one; "group hysteria" or "death wish," others. But these bits of psychological—and anthropomorphic—phraseology really say little or nothing. The fact is that groups of apparently healthy animals will drive themselves onto the beach, where they suffocate or die in the sun. A further fact is that, if forcibly hauled out to deeper water, the animals will swim back up on the strand. One dubious theory sometimes offered to explain these mass strandings is that the school follows a "pilot." If something happens to this animal, the whole school goes awry. But not nearly enough is known of pilot whale behavior to verify this theory. All that we can say is that these are highly social and group-dependent animals, and the reason underlying mass strandings may be related to that fact. As is well known by the Newfoundland whale drivers who herd their quarry to the beaches for the slaughter, schools of pilot whales can be driven to strand themselves in seeming panic. As we have noted, many strandings involve apparently healthy animals. If stress is a factor, perhaps examination of the endocrine glands—particularly the adrenals—will yield a clue as to cause.

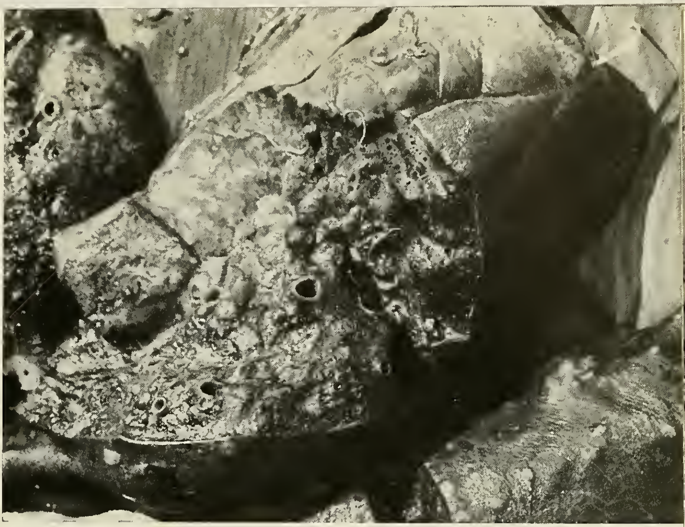
As to isolated strandings, the question is: why should an intelligent animal, equipped with an effective navigational system, be trapped in shallow water? Probably the correct answer in the majority of cases is that the animal is not in good health. Whale and porpoise may be as subject to sickness as other mammals. Autopsies of our stranded individuals indicate that some cetaceans are subject to such diseases of the respiratory tract as pneumonia. They also reveal that several roundworms parasitize both heart and lungs of some individuals, in addition to the many roundworms and flatworms common in the liver and digestive tract.

Thus it may be that a respiratory disease or parasitic infestation "gets ahead" of an individual animal which, as it becomes moribund, tends to fall behind the rest of the school. If far from land, it might die and sink to the depths of the sea or be attacked an eaten by predators—sharks or kille whales. Possibly, sick individuals th reach the protection of shallow wat may actually seek the support of lan for their tired bodies.

Let us take as examples three Ea Coast Atlantic strandings of 1960. C May 13, a pilot whale, 12 feet 9 inch long, was stranded on Brighton Beac scarcely half a mile from the Ne York Aquarium. With the aid of t New York City Park Department, wooden sled, and a tractor, we r trieved the animal and it lived in o tanks for 29 days. On July 4, 1960, 10-foot beluga was captured fro very shallow waters at Prince Edwa Island, Canada. It had strayed in the Kildare River, far from its norm summer range in the St. Lawren River, and had lived alone there f over a month until it was captured local fisheries officers. It lived in ca tivity for 64 days. Finally, a 7-foot inch common dolphin, *Delphinus d phis*, was stranded on the easte shore of Staten Island on December It was looked after by police until arrived, and lived with us for o four days. These three are not the o cases we have met locally, but are only cetaceans brought back alive.

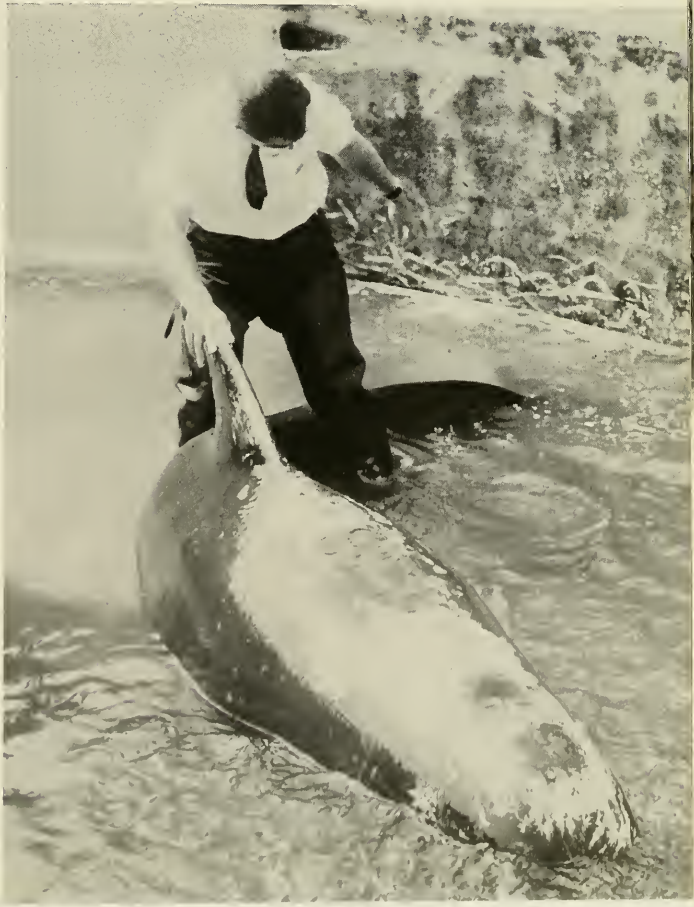
We suspected at the outset t all these animals were sick wl they were stranded or captured waters strange to them. We knew t would probably die in a short ti

tarts in center of the jaw and then noves to the front and to the back.



Infected lung of dead pilot whale had multiple abscesses and parasitic worms.

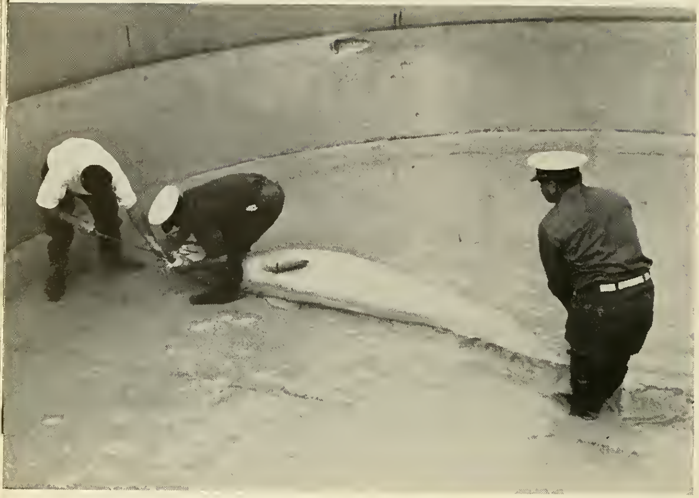
Author, *below,* treats a pilot whale with antibiotic and sunburn preventive.



ut we made every effort to effect a ure. even though we were in the dark s to the nature of the diseases. The ongest that any stranded cetacean has ver lived in captivity is seven months.

Even though we had little hope of uring the animals. there was much we ould learn by keeping them alive for ven a short time. In the three cases ited. we were able to take live weights hen the animals reached our doors r whole weights at death—informa- on that is rare indeed. We were also ble to make photographs of the whole nimals. and of various surface fea- res—squid tentacle marks on the ilot whale. and circular marks on the eluga that looked surprisingly like e work of lampreys.

There was a major problem in ansporting these three animals to the quarium alive. Cetaceans are not lapted for life out of water. but they n be transported that way. Usually, ey are carried on slings of thick rub- r mattresses or on air mattresses. hey are placed on their sides to re- ve weight from the chest, and the dy is covered with a light sheeting at is kept constantly wet to keep the imal moist and cool. Pictured on p. is the beluga. which was trucked in large wooden tub and partly covered ith water. Under the animal. as cush- ning and support. and to give stabil- , were many burlap bags. The water, o. helped relieve the weight on the imal for. as stated earlier. when out the water weight is the whale's



Squid are wrapped around a stick and force fed to beluga that would not eat.

Although it took three men to perform task, whale did not object strenuously.

worst enemy. It is not too serious a problem with small cetaceans, but can be critical for larger ones.

We dosed our captive animals with penicillin and streptomycin, and even with vitamin shots and tranquilizers. Although the results were hard to assess directly, we have accumulated some knowledge of the dosages required for handling and treating these three species. On the whole, we suspect that except for certain tranquilizers to which these animals may be sensitive, the dosages are not atypical of other mammals. Under the direction of Dr. Ross Nigrelli, pathologist of the New York Aquarium, and with the co-operation of several physicians, eyes scraped or partially punctured by beach sand were cured, sunburn alleviated, cuts and abrasions healed.

Feeding was the greatest problem. Before using any forceful methods, we continually tossed dead fish and squid to the animals, and even placed specially collected living fish and squid into their tank. On its second day in captivity, the common dolphin surprised us by feeding heavily, and continued to do so until the day before its death. The pilot whale and the beluga steadfastly refused the food handed to them by a swimmer in their pool or tossed to them. In consequence, we developed a technique of gentle force feeding. Twice each day we drained the pool of all but a foot of water. Three men then went in with the whale. One took up his position at the animal's tail and two stood at its head. The mouth was gently pulled open by one of the two "head" men. The whale did not particularly resist this manipulation. The other head man thrust a morsel down the whale's throat to the back of the tongue. The whale was then allowed to close its mouth, and the fish was swallowed voluntarily. Only toward the last days of life did any regurgitation occur. We learned that a bit more than 25 pounds of squid could be given to our pilot whale at a "sitting," and almost 20 pounds to the beluga. It is doubtful if either of these sick animals would have lived so long without this feeding technique.

We could observe only a few things about the behavior of a sick, none-too-active cetacean in captivity. We did manage to evolve a rough sort of "index of stress," based on the animals' breathing rates. When first brought to our tanks, the intervals between breaths were short, as was the duration of the breath; respiration was not unlike gasping. We have the best records for the pilot whale and the beluga. Both began with breathing intervals of approximately $\frac{1}{4}$ to $\frac{1}{2}$ minute. This interval lengthened over a period of a few days until a pattern was set up, characteristic for each individual. This consisted of one or more long intervals—from nearly one min
ute to two minutes—with several short
five- to thirty-second intervals be
tween. These shorter intervals in suc
cession resembled the human diver'
technique of hyperventilation as
means of "storing up" oxygen. At th
point when this more regular breath
ing pattern is adopted, the animal ma
be assumed to be accustomed, compa
atively, to its confined surrounding

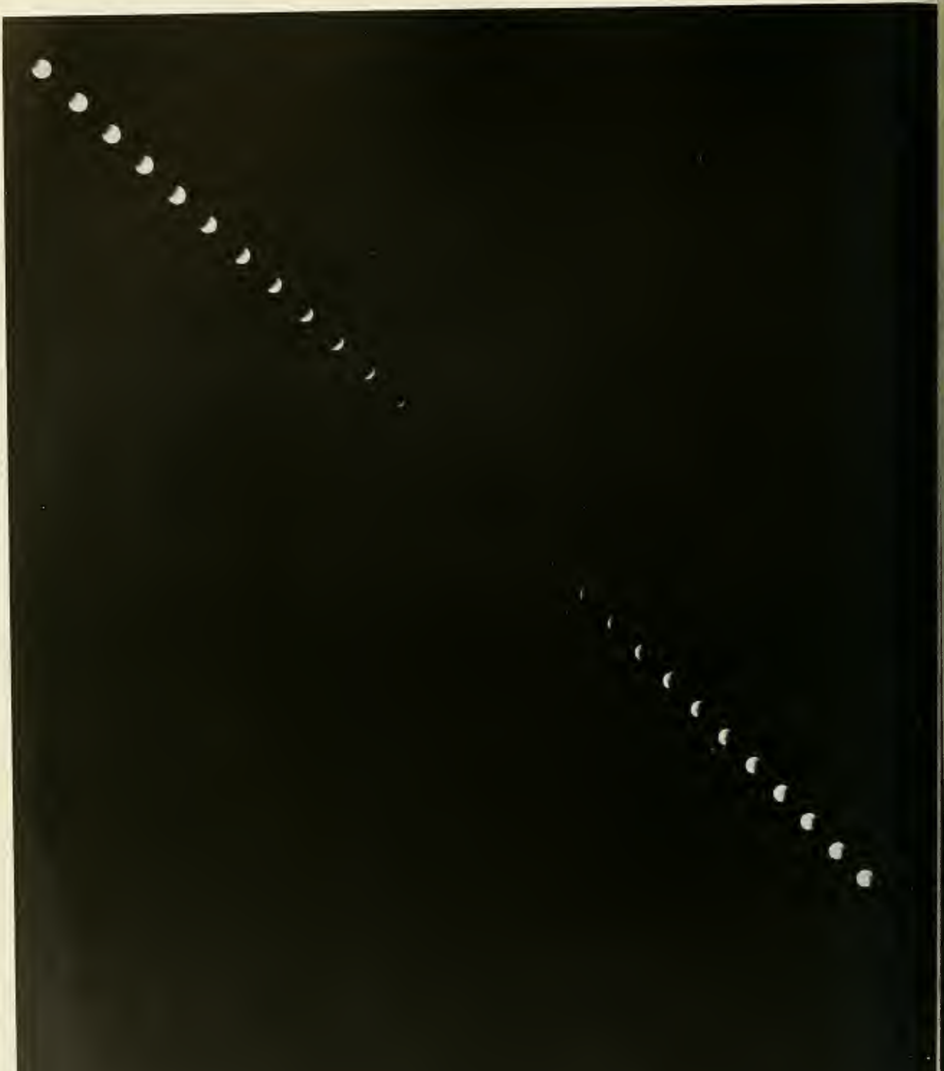
Dr. Ray, Assistant to the Director of the New York Aquarium, is known widely for his popular writings and for his photographs of marine life.

We also noted that the pilot wha
is less maneuverable than the e
tremely supple beluga, which is able t
scull with its tail to swim backwar

Another remarkable thing we note
during the short lives of these sick a
imals was their extreme gentlenes
Only the beluga attempted to bite, ar
it was not a hard bite at best. Occasio
ally, our patients snapped their jav
threateningly—but for the most pa
the animals were docile and easily ha
dled. The pilot whale seemed to reco
nize one keeper who often swam wi
it, or at least it recognized the keepe
good intentions. We discovered th
this animal enjoyed having its su
burned skin scratched with a piece
rough netting, so daily it was acco
modated with this treatment.

Eventually, all three animals di
Autopsy by Dr. Nigrelli reveal
a remarkable coincidence—all th
had suffered from advanced cases
pneumonia, the lungs being absces
and full of pus. Roundworms were
sociated with the infection in the pi
whale and the beluga. This coincide
is fortified by another case. A loca
stranded harbor porpoise, which
not reach our tanks alive, showed
same condition of advanced lung
fection and parasites. Whether
parasites have anything to do with
animals' susceptibility to pneumo
is not known. What we can say, on
basis of our experience, and that
others, is that cetaceans stranded al
will probably have respiratory in
tions. If such diseases involve diffic
in breathing, which seems likely
may well incline the animals to s
calm, shallow waters and even
fatal pillow that the beach affo

Mouth of the beluga is held open w
squid are pushed to back of the ton



Near-total eclipse, due on August 25, will almost equal spectacle seen ab e.

CELESTIAL EVENTS

list of astronomical occurrences for the second half of 1961

By K. L. Franklin

JULY

July 5: The earth is farthest from the sun on this date—.6 million miles.

July 19: For the next twenty nights the fleeting streaks light seen occasionally in the sky may be associated with e meteor shower named for the star, Delta Aquarii. The aximum count one observer could expect is about twenty eteors each hour about July 29. Unfortunately, the moon ll be just past full at that time, and will seriously interre with observations.

July 26: The moon will be closely followed across the y tonight by Saturn and Jupiter.

July 27: The moon will pursue Saturn and Jupiter toght, following Jupiter by 5° about 11:00 p.m., EDT. atch for this celestial leapfrog until November.

AUGUST

August 10: For the next five nights the Perseid meteors ike their annual appearance. After midnight, one obver may count nearly one meteor per minute. A true mber of the shower will appear to streak away from a int in the constellation of Perseus, low in the northeast . Sporadic meteors will not show this characteristic.

August 11: An annular eclipse of the sun will be seen s morning in the South Atlantic Ocean. No significant rt of the path will cross land, but parts of South America d South Africa will experience a partial eclipse. The ipse is annular (ring-shaped) rather than total, because moon is 252,500 miles away at this time, nearly as far m the earth as it can get, hence appearing about 7 per it smaller than the sun.

August 25: People near the ocean may wish to know it unusually high and low tides will occur this afternoon l evening, because the moon will be only about 222,000 les away, just before the moon is full.

Of more astronomical interest, however, is the nearly al eclipse of the moon that will take place this evening almost all of the Americas. After rising, the moon will dually darken on its eastern side, and will obviously er the deep shadow of the earth at 9:35 p.m., EDT. The pest penetration will occur at 11:08 p.m., EDT, and moon will leave the umbra 12:42 a.m., EDT, August Only the Pacific coast will not be able to witness the ire umbral passage, because the moon will rise there out a half-hour after this phase begins.

SEPTEMBER

September 19: About 9:00 p.m., EDT, the gibbous on will appear above Saturn and Jupiter, in eastern gittarius, making a nearly perfect equilateral triangle h the two planets. This figure on the sky affords a fine ortunity to notice how rapidly the moon moves against background of heavenly objects—approximately its own meter (2,160 miles) every hour.

September 23: Autumn begins at 2:43 a.m., EDT, for Northern Hemisphere and spring begins "down under," when the sun crosses the Equator, heading south.

September 29: The gibbous moon will pass directly in front of Aldebaran before 3:00 a.m., EDT. Those who wish to stay up for this interesting occultation should not go to bed on the night of September 28.

> The Celestial Sphere
>
> Everyone is aware of the enormous distances to the things we see in the sky, but these celestial objects seem to be attached to the surface of a real sphere of which we are the center. The illusion that all objects appear to be the same distance from us is due to the fact that we cannot *sense* any differences in their distances. An example of great differences actually occurring in our solar system is provided on September 19: The moon is 224,100 miles away; Jupiter, 420,000,000 miles; Saturn, 885,000,000 miles.

OCTOBER

October 11: Early risers who wish to see Uranus may find it less than one-third of a degree north of Regulus this morning. This star, the brightest in Leo, is about the first magnitude on the astronomical brightness scale, but the planet is about the sixth magnitude, as faint as the average person can see without optical aid.

October 29: This morning, 2:01 a.m., EDT, becomes 1:01 a.m., EST. Daylight Saving Time ends in many parts of the United States. Set your clocks *back* one hour.

NOVEMBER

November 13: A short time after sunset this evening, Saturn, Jupiter, and the crescent moon form their monthly tableau low in the western sky.

November 23: This evening, the moon will again occult Aldebaran, the bright, orange star in Taurus. Although the star is bright, the moon is only a half-day past full. Binoculars will help in observing this event.

November 29: This morning the moon occults the bright star Regulus. It will be dark on the Pacific coast, but eastern observers should use a telescope to time the event.

DECEMBER

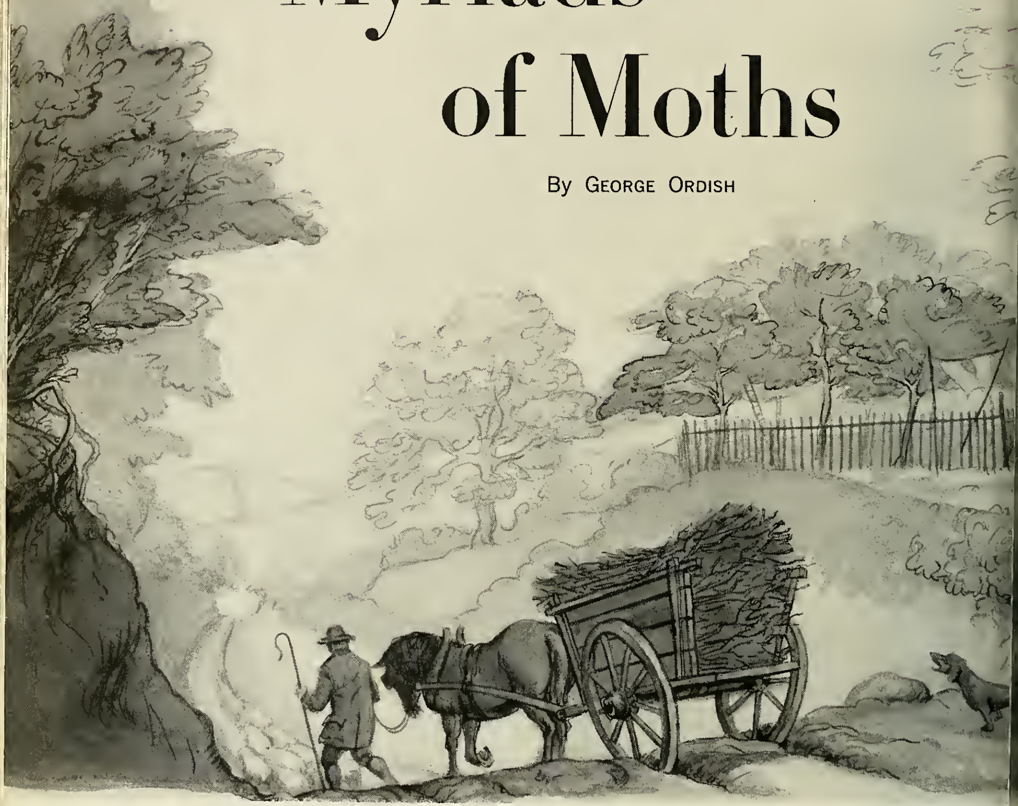
December 10: Clear, crisp nights and a moon setting fairly early will help in the observation of the Geminid meteors this week. One observer may see about fifty an hour by the thirteenth of December and, occasionally, a brilliant fireball associated with this shower.

December 21: At 9:20 p.m., EST, the sun has reached its most southerly point in the sky, the winter solstice. Although summer begins in the Southern Hemisphere, the days up north will begin to lengthen, promising spring in spite of the months of winter weather that still lie ahead.

Dr. Franklin of The American Museum—Hayden Planetarium prepares this summary each six months.

Myriads of Moths

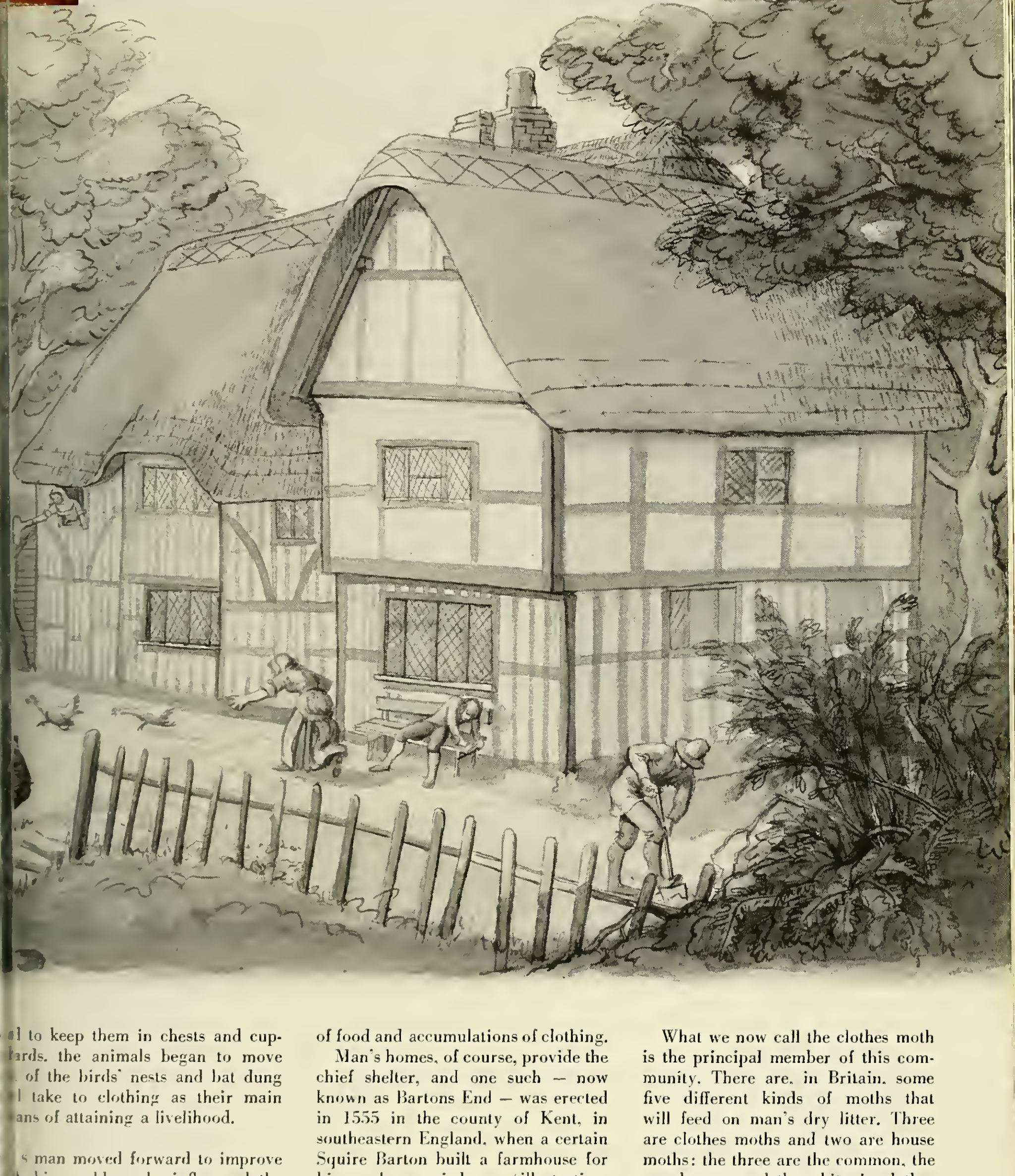
By George Ordish



Under natural conditions, the animals belonging to the dry-litter habitat are rare, because of the scarcity of dry litter in nature. Wet litter is very common, particularly in the woods, at the foot of cliffs, and so forth, where rotting vegetation, dung, and animal remains may be found, together with a special fauna—such as earthworms, wood lice, springtails, mites, and millepedes—all living in and on these wet-litter substances. By contrast, dry-litter habitats under natural conditions are found only in the nests of certain birds—those placed on cliffs or in dry caves, for example—or in a few dry deposits of dung from bats or birds. These are very rare positions compared to wet-litter sites, but they contain their own special fauna.

The dry litter tends to consist of high-protein material such as waste hair, feathers and fur, or dung, which has a high nitrogen content. The creatures living in dry litter, or some of them, were first of all predators on other small animals and then became scavengers of such discarded materials of higher animals as molted feathers and hair, cast snakeskins, and dung. They lived specialized lives within their unusual realm and had to perfect devices that would economize water, the scarcest material in their chosen environment.

When man came on the scene, he had a considerable effect on these re animals, because he was a great e-ator of dry litter himself: he lid dry places — caves, huts, castles, d houses — which he would keep wan and, to begin with, not particul clean, so that a vast new dry-lier habitat was created. Even though e was not covered with fur, did not lt or cast his skin, and did not le his dung in his own abode, yet e started to wear clothes and scatt d bones with meat on them about e floors of his caves, huts, and cas s. His first clothes (skins and fur) re to those dry-litter animals a huge p- ply of their chosen medium, an as man began to weave coverings of ol



l to keep them in chests and cup-
ards, the animals began to move
of the birds' nests and bat dung
l take to clothing as their main
ans of attaining a livelihood.

s man moved forward to improve
his world, so he influenced the
of many other creatures; he
atly increased the opportunities
l numbers of these erstwhile scav-
ers, a step that caused considerable
oyance to their hosts. They did
, however, abandon their old sphere
l are still found in birds' nests and
osits of dry droppings, and fre-
ntly it is from these sources that
creatures spread into man's stores of food and accumulations of clothing.

Man's homes, of course, provide the chief shelter, and one such — now known as Bartons End — was erected in 1555 in the county of Kent, in southeastern England, when a certain Squire Barton built a farmhouse for his newly married son (illustration, *above*). Its first inhabitants, though, were not the newlyweds but woodborers, already present in the very timber used in the building. As successive generations of animals and men passed through this house, various cycles of life forms entered an organic pattern to make what might be called "the living house." One such is that of the dry-litter community.

What we now call the clothes moth is the principal member of this community. There are, in Britain, some five different kinds of moths that will feed on man's dry litter. Three are clothes moths and two are house moths: the three are the common, the case-bearer, and the white-tip clothes moth; the two house moths are the white-shouldered house moth and the brown, or false, clothes moth. To

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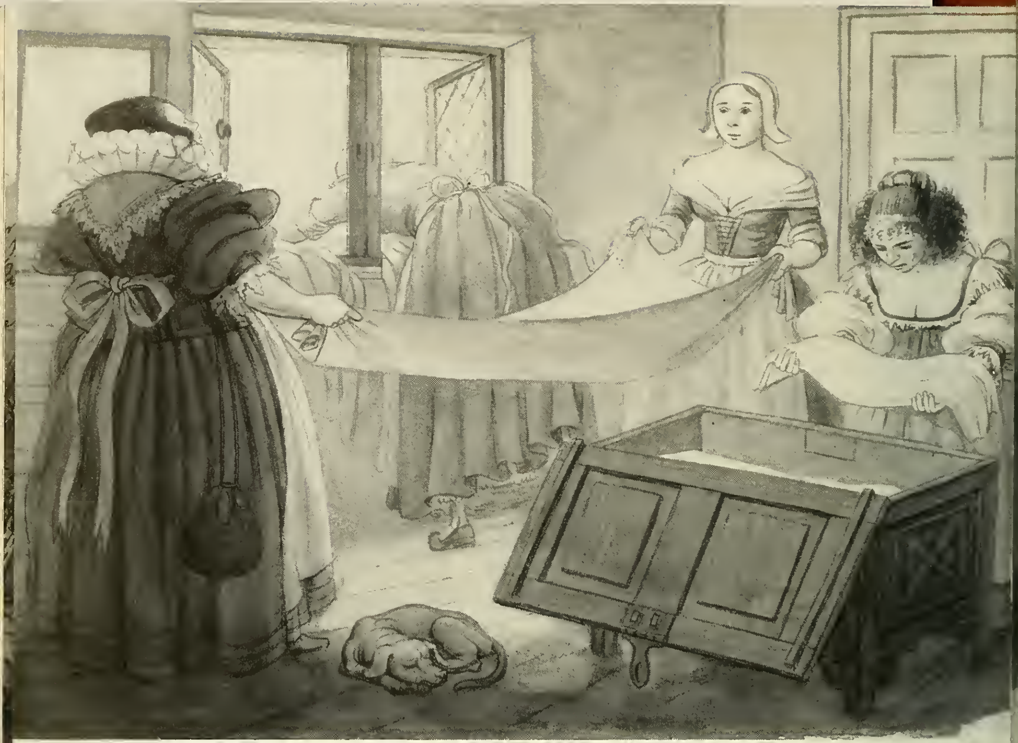
MR. ORDISH is an entomologist and economist whose work has taken him across the earth. Presented here is an excerpt from *The Living House*, Copyright © 1959 by George Ordish, published by J. B. Lippincott Co.



Techniques of moth prevention were not really grasped by 17th century inhabitants of Bartons End. When storing clothes in "mother's moth-proof chest," they believe was sufficient if the garments were free of all obvious

these must be added the spider beetle and the carpet beetle, which operate in much the same way as do the clothes moths. The furniture mite is another animal that belongs to this group, and there are many more that have specialized in sharing man's stores of food. The flour beetle is among the commonest, but others, as the Indian meal moth, the grain and rice weevil, the fruit moth, and the bookworm, have been added as trade and commerce interchange both animals and goods from one part of the world to another.

These were the main dry-litter creatures that fed on man's goods at Bartons End, but they were not the whole dry-litter community. There were a number of other creatures that benefited from these sheltered conditions. Silverfish gradually developed in the house, but did not do much damage; they are the most primitive of all insects and can be described as living fossils, though very minute ones. The Bryobia mite, or grass spider, frequently came to the house to pass the winter and was fond of the thatch, the lower and upper layers of which formed part of the dry-litter habitat, particularly by 1660, when six layers of new thatching straw had been laid on the roof without all of the old thatch being completely removed from under the new layers.

Here, mites, psocids, silverfish, springtails, fleas, Protura, and even wood lice abounded. But much of this old thatch was moist because it was in bad condition, being so thick that it never fully dried out. Consequently not all the thatch can be considered as the dry-litter world. Moreover, it was not a high-protein dry area, but a comparatively low-protein, high-carbohydrate zone. Many of the scavengers here were actually living on molds growing on the straw rather than on the straw itself. Strangely enough, the top layer of thatch was more often dry than wet, because the wind or the sun dried it so quickly after rain, but the variation made it an unattractive habitat.

Clothes moths were well knowr to the Elizabethans; their clothing wa of wool, linen, and leather — with a l le silk provided for the most wealth — and all these except the linen w ld be attacked by the clothes mo s. Brushing, airing in the sun, put g the clothes away clean, and la g lavender and laurel in the clo es chests were the methods Mary Ba n used to combat the ravages of t se insects. They were effective, too x- cept perhaps the lavender, though s may have had some slight repel nt action on the adult moths), and e- main so to this day.

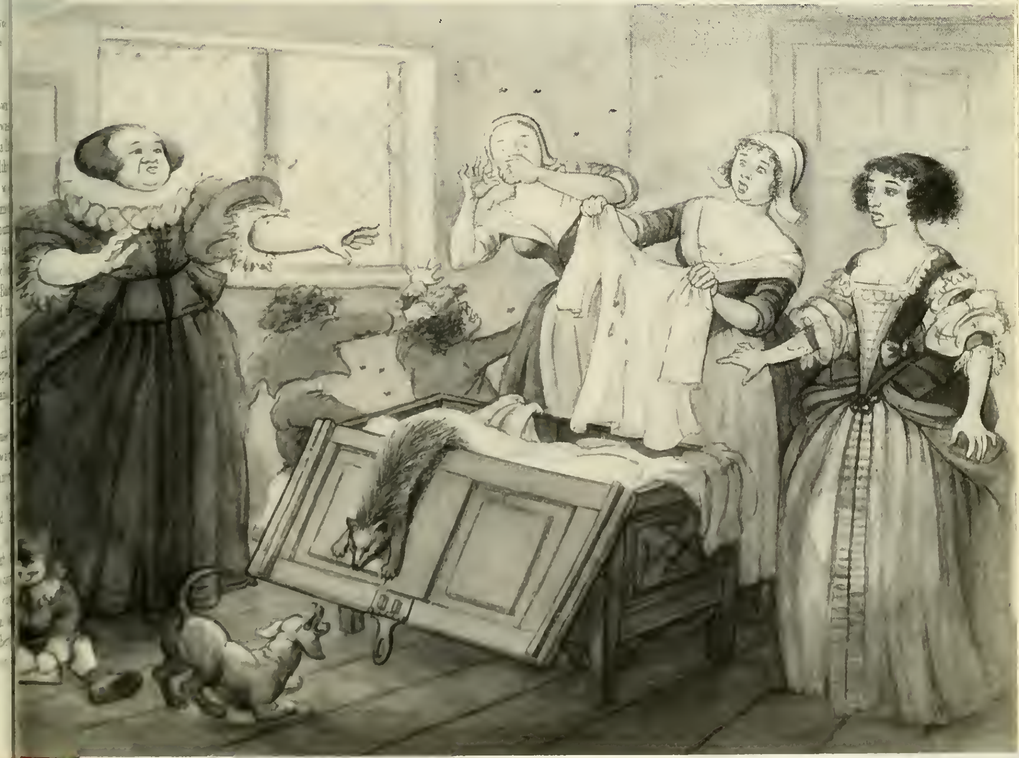
Through the centuries the house as improved so that it was kept war er and the clothes moths thrived inc s- ingly. Now that the present ow rs have the place centrally heated, t re is another crisis in the lives of he clothes moths because, though ey like the heat, it is becoming too dr or them. Moreover, mothproof ca ts and clothing are an additional b ke on an increase in their numbers as are artificial fibers like nylon nd ylene; neither are modern manutured woolens all that a clothes th wants, for it will breed much re quickly on raw wool, which obusly contains some vital substance relative abundance, compared with manufactured article. It is only clothes moths that have completely ıpted themselves to living on fab; if the clothes are clean, moths can on them but they prefer soiled terial, containing sweat, food, or rement, which enables them to ob1 supplies of vital elements (possicertain fats, vitamins, and amino ds) more readily than from clean ric alone. This is one of the reas why putting clothes away clean os to protect them from moths. ally, moth powders and sprays ed on DDT are a serious threat to se moths' survival as a race. Toher with their enemies, the spiders, are declining, though by no ıns extinct as yet. Still, they have rcome many setbacks in arriving heir present way of life and, breedas fast as they do, they may yet overcome these new-found difficulties.

Here we can see the struggle for survival imposing this pattern of life on the clothes moth. A medium containing food material, protein, carbohydrate, vitamins, and water, albeit this last was comparatively scarce, offered itself and was duly colonized. To do so the creatures had to acquire some special habits, for they had to be able to digest the fibrous proteins found in wool, hair, and leather — such as keratin and fibroin — which are digested by few animals. Nevertheless they have done so; they had to, or else leave the field untouched. Measurements have shown that about half of the fabric consumed is actually used by these animals, and the rest is excreted after very slow digestion.

THE creatures can readily obtain oxygen from the air. Their large surface area, compared to their weight, makes this easy as they breathe through pores in their skin (spiracles) not by means of lung books. The larvae live on or in the medium the whole time so the question of water supply is important. As they breathe they lose water; they obtain very little with their food, for wool and hair do not contain much of this substance so essential to life; to overcome this difficulty they have acquired the ability to absorb water directly from damp or dampish air. By this means their vital supply of water is maintained. They are able to vary the length of their larval life considerably, which fact also has a notable survival value. When food of the right kind is scarce or water cannot be obtained either from food or the air, the larvae can rest or develop more slowly and into a much smaller adult — perhaps a tenth the weight of the normal insect — though still, if a female, able to lay fertile and viable eggs.

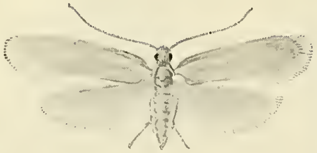
The drying of the atmosphere of the whole house by the central heating system is a big threat to the way of life of the clothes moth for it makes the question of water supply acute. On the other hand, it also provides warm conditions all the winter, thus

) YEARS LATER, when the chest was reopened, the women ·onished to see a swarm emerge from the moth-eaten clothes. They did not realize that the stored clothes had moth eggs on them that hatched and thrived in the chest.



CLOTHES MOTH

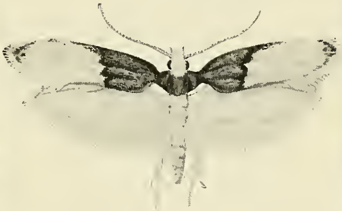
Male 5/12" to 1/2"
Female 1/2"+



TINEOLA BISELLIELLA
Common Clothes Moth

CLOTHES MOTH

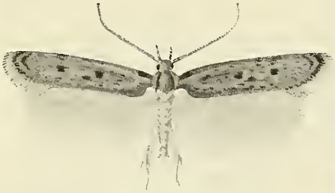
Male 1/2" to 2/3"
Female 5/6" to 1"



TRICOPHAGA TAPETZELLA
White-tip Clothes Moth

HOUSE MOTH

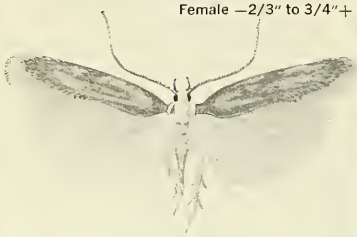
Male 2/3" to 3/4"
Female 3/4" to 1"+



HOFMANNOPHILA PSEUDOSPRETELLA
Brown House Moth

HOUSE MOTH

Male –1/2" to 7/12"+
Female –2/3" to 3/4"+



ENDROSIS SARCITRELLA
White-shouldered House Moth

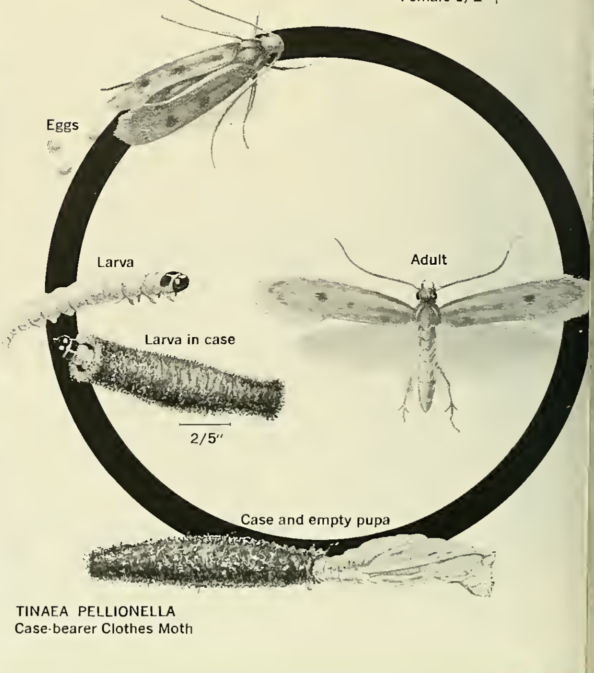
shortening the life cycle and enabling the generations to succeed each other more rapidly, which causes their numbers to build up again. The balance between increase and decrease is a narrow one: very small things may make all the difference to the success or failure of an animal. However, clothes moths are not very likely to become extinct so long as birds are encouraged. While sparrows can force their nests under the guttering or eaves, and martins build on the walls, there will always be a supply of various of these creatures ready to find their way into the house, with its vast supply of dry litter. As soon as a dry-litter animal finds itself in a favorable position in a house, its numbers will build up very quickly.

FIRST of the clothes moths at Bartons End was the common clothes moth found in the sparrows' nests under the thatch of the eaves. The tiny eggs of this creature are oval and ivory-white in color; found singly or in groups of two or three, they are laid on top of tight-woven fabrics, or
between the strands of wool in
kets and looser woven cloths,
the base of hairs in furs. Some
eggs are deposited by each fe
but the quantity naturally depen
how well fed the moth was befo
pating. Shortly after laying the
the female dies; the eggs hatch w
a week or ten days' time. The l
are white with yellowish-tawny
and are about three-eighths of ar
long when fully grown. As so
they hatch, they begin to feed o
"dry litter" on which the eggs
been laid. When faced with mi
of animal and vegetable fibers
moths seek out and consume on
animal ones. The material, if co
shows through the skin and mak
larva inconspicuous, a fact wit
siderable survival value. Many
maids and mistresses at Barton
were not sharp-eyed enough to
the beginnings of an attack o
blankets, jerkins, hose, and m
dinous succession of garments
long history of the house, and sc
the tiny, vulnerable caterpillar
portunity to develop to maturity

Illustrated by Enid Kotschnig

THE LIFE CYCLE OF A CLOTHES MOTH

Male 2/5" to less than 1/2"
Female 1/2"+



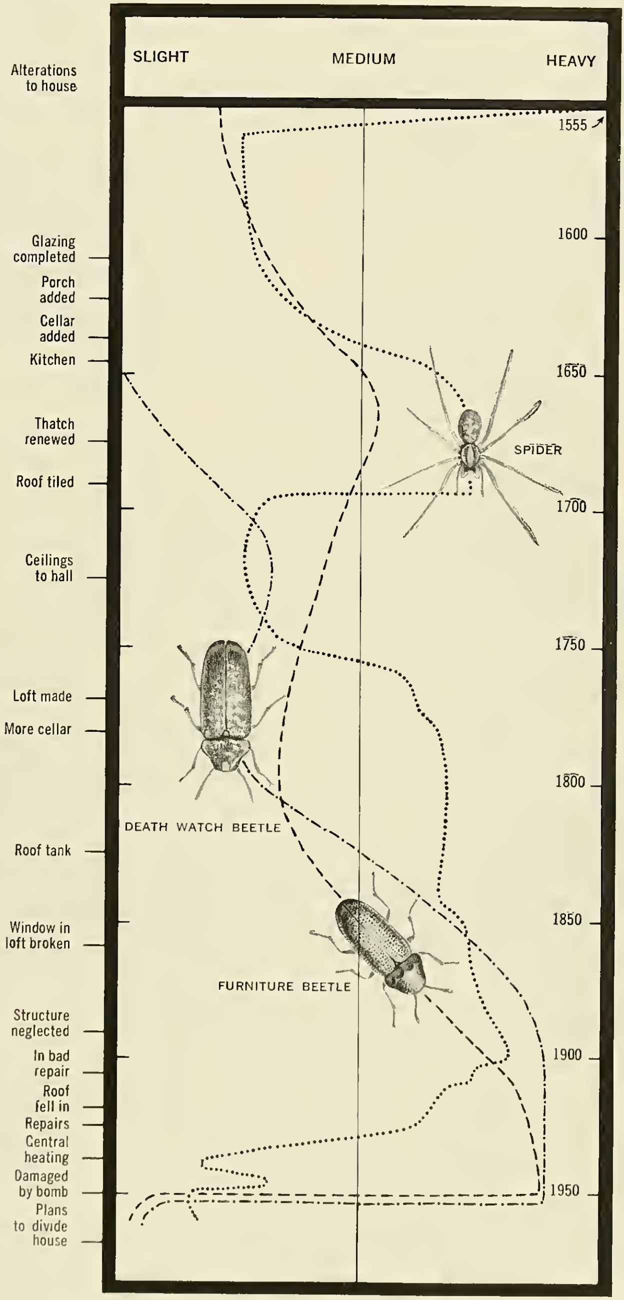
TINAEA PELLIONELLA
Case-bearer Clothes Moth

The common clothes moth larva ısually builds a tube from silk and he fibers of the food medium on which has been feeding at the time, proecting its head from either end to eat. Vhen a new area is to be browsed, the ırva either extends the tube or abanons it and constructs another one. ot all larvae do this; a few are freeeeding over the area, or just spin a ttle web silk to protect themselves. Iere again is posed a question as to ıe balance of advantages to the race. 'he tube protects the larva against ertain parasites but renders it more onspicuous to man, while the freeınging larva is less conspicuous to ıan but more exposed to attack from hneumon and braconid parasites. hich is the greater danger?

The noise of a moth feeding, when mplified by microphone, is very artling — a vast tearing and rending f fibers repeated in a rhythm of three four bites, followed by an interval f two or three seconds' silence, and ıen repeated. It is indeed fortunate r the moth that our unaided ear canot pick up this sound, for such an arming noise would not only adverse the presence of the moth but lead instant defensive action as well!

ARVAE of the common clothes moth by no means confine their feedg to wool and fur. At Bartons End, oisoned mice sometimes died behind e wainscots and these were attacked a number of insects, including the othes moth. The poison victims oved a valuable source of moisture the moths, for not only was the fur ed but the drying, but still moist, sh on the mouse bones was also colnized. However, this attractive source food also had its dangers for the oths, for those that attacked the omach and viscera were killed by e same arsenical or phosphorus poin that had killed the mice. The moths tacking the dead mice helped deoy the body more quickly and were vantageous to man in this respect. ıe action of the humans at Bartons ıd to reduce one animal obnoxious them had the effect of increasing opportunities for development of other equally objectionable.

The moths also occasionally made periments in living on purely vegeıle materials. In the early days of house, they successfully managed develop on a few porridge oats lyneglected in a sack, and on some



FLUCTUATION in populations of three other non-human residents of Bartons End is shown on graph in relation to man's alterations over the centuries.

crushed barley fallen into a corner in the brew cellar. However, in these cases, they always concentrated on the high-protein portion of the vegetable material. They also attacked garments of both silk and leather.

The ancestors of this moth seem to have lived as predators on the larvae of ticks, mites, and similar creatures and from this to have adopted the scavenging way of life as being easier; they then pushed on to attack man's goods. It appears a most adaptable animal and may well have genes in its makeup that will again face man with a new development. Nylon may perhaps fall into its power: it has already attacked the insulation of telephone cables in London.

After the larva comes the pupa: first a silken cocoon is spun, and attached to it are threads of the material on which it has been feeding. This economizes on the silk it has to spin, leaving more food reserves for the succeeding adult and the future generation, and is also an aid to concealment. The pupal case is formed within the cocoon: the duration of this stage is variable, lasting from two to six weeks, a lower temperature prolonging the process. At the end, the pupal case projects from the cocoon, splits at the end, and the moth emerges.

The newly hatched moths are a bright, golden-buff color, the wings free from markings and with rather loose scales, some of which easily become detached. The wing expanse is about half an inch, the males being a little smaller than the females. The female is full of eggs and rarely flies as she is so heavy; moths seen on the wing are nearly always males, or spent females who have already laid their eggs in some well-concealed spot and are then light enough to fly.

AT Bartons End, the humans always chased and killed any small moth seen fluttering in the house. This did very little to keep down the population of clothes moths, because some victims were garden moths drawn to the lights at night or, if clothes moths, were the males or empty females who were about to die in any case. Of course, if enough males could be killed, the future population would be affected. But killing a few males will make very little difference to the numbers of the next generation, a fact which is true of most of the animal kingdom and is no doubt the reason why only men used to go to war and women did not. The moths, particularly the females, try to escape danger by running for shelter in quick, dodging, characteristic dashes, though sometimes they take short flights as an additional measure of evasion.

The length of life as an adult is again very variable; the males live longer than the females, the former averaging about four weeks and the latter half this time, or a little more. The adult moths tend to be abundant in early summer and in the autumn, but now at Bartons End they may be met with all the year round (owing to the central heating) although not in the large numbers that were known in the earlier days of the house.

IT was generally concluded in the seventeenth century that insects and creepy-crawlies in general were spontaneously created out of "corruption": that rotting meat engendered maggots; dung, flies; and shut-up clothes, moths. The mistress of Bartons End at this time accepted this to some extent, but noted first that the clothes were not rotting and, secondly, that the maggots in the clothes turned to moths. Hence she argued the moths could turn to maggots. There was even some confusion over the name, for the word "moath" had once meant the maggot, but now meant the flying creature, which to her suggested a close association between them. Ever practical, she decided to try keeping the moths away from the clothes by having a chest made with a very tight-fitting lid. Fortunately the clothes she put into it were free of eggs and larvae, so her theory was triumphantly vindicated.

But one of her daughters was not so successful with "mother's moth-proof chest," which she left full of clothes unopened for two years. Moth eggs had gone into the chest on the clothes when first put there and throve in their closed community, for it happened that no parasites had gone in with them, nor could they get in, to restore the balance. Mother's moth-proof chest became a family joke.

William Harvey, the king's physician, published his book on the engendering of animals thirty-seven years before the unfortunate daughter's parent died, and his dictum — "Omne vivum ex ovo" — had appeared in one of the newsletters that the country family received from London from time to time. This had greatly intrigued the mother, though it did see to flout the Old Testament, for di not the Book say "Out of the lion cam forth sweetness"?

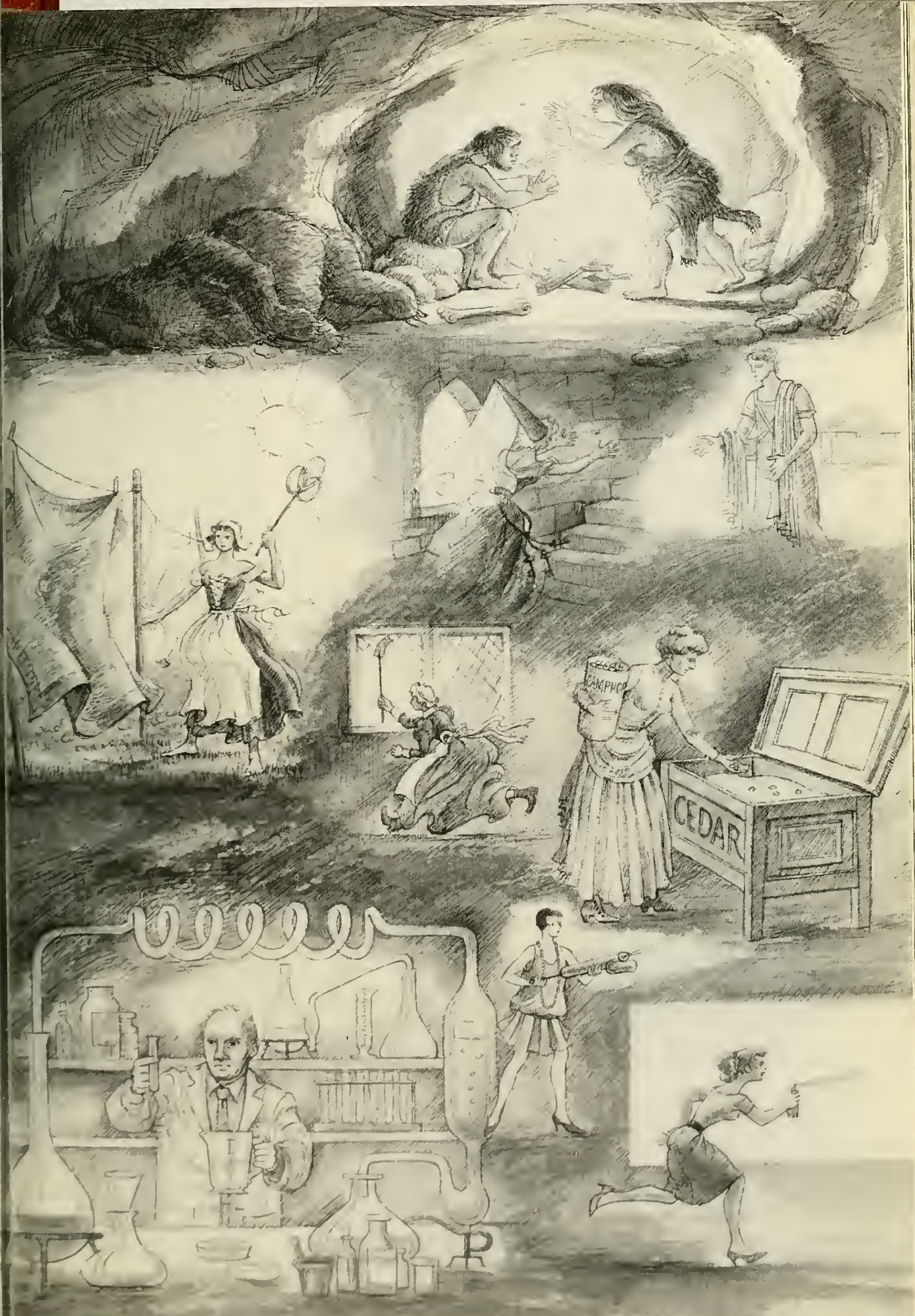
How often at Bartons End did th humans go to their stores to take o a special garment and find it mot eaten! What feverish last-minute r pairs were made; what firm resol tions were passed never to let it ha pen again, only to be broken and th cycle to repeat itself. The moth po ulation grew to its height in the la half of the nineteenth century.

The population built up then b cause anything unwanted was pushe into a corner, or into the loft, a mir mum of cleaning was done, and all th scavenging insects throve. When th last tenant left in 1899, the moths we in no small degree responsible for th dirty state of the house. The house r mained empty of man for the next t years, and the moth population f very rapidly. It was no longer war and the almost inexhaustible supp of dry litter — continually provid by man — ceased to come forwar The population of the common cloth moth was almost nil in 1909, the ye the next owners bought the pla Only a few moths were left in that co stant source of material — the bir nests lodged in the eaves.

BECAUSE the clothes moths ha proved such a continuous n sance to man, they have had one f reaching effect on him. The inse cide DDT was discovered while l Müller, a Swiss chemist, was looki for new moth-proofing agents for f rics. DDT is such a powerful inse cide and can kill so many disea bearing insects (malaria mosquito plague fleas, and typhus lice, to na a few) that millions, who would the ordinary way be dead from th causes, are now alive and healthy.

Would DDT have been discove so soon had the clothes moth not b so persistent? Taking this into acco t we can perhaps say that the moth s been beneficial to man, for it has k t down many murderous diseases. n the Second World War, for the f t time in the history of war, more peo e were killed by bombs and bullets th n by disease: truly, man has progress l.

AN ADAPTABLE PREDATOR, the moth plagued man for millennia, but mod n chemicals threaten the animal's fut e.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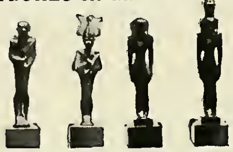

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VASHINGTON NEWSLETTER

By Paul Mason Tilden

HE OPENING DAYS of the new Congress—the eighty-seventh such body deliberate on matters touching the elfare and future of the nation—ought the usual torrent of proposed w legislation. contents of which nged in gravity from a proposal to event the use of stop watches or other easuring devices in the postal service creation of a national peace agency.

Many of the hundreds of bills dumped to the legislative hopper by House and nate members will die in the dusty geonholes of legislative committees d subcommittees. Some will be re- rted favorably and reach the floor Congress for examination, debate, nendment. recommittal, rejection, or rhaps eventual passage. The percent- e of projected legislation arriving at is very last category will be small in- ed compared to the mass of proposed wmaking during the session.

A number of the bills filed during the rly months of Congress were con- rned with conservation matters; sev- al of these will be mentioned here.

The National Parks

NE of the nation's leading authorities on national parks remarked that st of our great primeval preservations me into the park system by default. saying this. he was in no way belit- ng the great services rendered the na- n in past times by the people whose ors brought into being such parks as llowstone. Yosemite. or Grand Can- n. What he meant was that vast tracts relatively unspoiled and sparsely set- d lands were still available. and that great majority of Americans were her unaware that such lands existed cared little of what became of them. tting these parks into the system was gely a matter of arousing sufficient ngressional interest.

such is not the case today. One need end only a few congressional hear- s on park matters to realize that, day and in the future, worthy areas l be added to the national park system only by way of the all-too-familiar "blood. sweat. and tears"—and, it might be added. by seemingly endless argument and untold reams of testimony.

The reason is obvious: today. there are 180 million people in the United States, with nearly that number of compelling reasons why additional park or recreational areas should be established on someone else's land rather than their own. Great tracts of land for national parks are simply no longer available.

With this in mind, it is understandable that a number of national park bills introduced into previous sessions of the Congress are back again in the Eighty-seventh, either in the same form or with certain revisions designed to meet previous objections. The most urgent of these, from the conservationists' point of view, are those calling for the establishment of a number of national seashore areas. Close to the hearts of both President Kennedy and Interior Secretary Udall is legislation providing for a Cape Cod National Seashore; Senators Saltonstall and Smith of Massachusetts, and Representative Keith of the same state have introduced new bills to bring such a park into being.

For Cape Cod, the year 1961 will be crucial. The tempo of commercial development, real estate speculation, and subdivision has increased rapidly since the National Park Service published its Cape seashore proposal early in 1959. Secretary Udall summed up the situation rather succinctly in an early March report to the House Committee on Interior and Insular Affairs when he said: "Unless action is taken in the near or immediate future . . . it seems quite evident that the Cape's traditional atmosphere and character will vanish under construction activity now underway. . . ."

The same could be said, with perhaps a bit less urgency, for another proposed national seashore on the opposite side of the nation. There, in Marin County, a few miles north of San Francisco, the National Park Service has proposed the Point Reyes Seashore (of some 53,000

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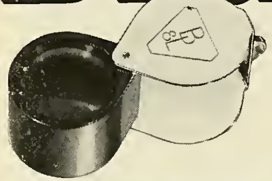

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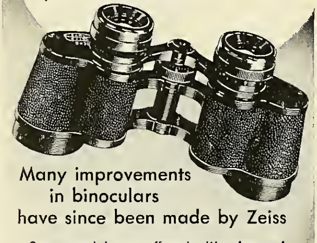

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acres) to preserve an exceptionally fine bit of California coastal terrain. Here the subdividers are also beginning to stir, and several bills have been introduced into both House and Senate to accomplish a park while there is yet a chance to do so.

Several Senators have co-sponsored a bill whose purpose is to authorize investigation, looking toward possible preservation, of a sizable number of lesser-known areas of great merit. Among these are Cumberland Island, Georgia; Channel Islands, California; Huron Mountains, Pictured Rocks, Grand Sable Dunes, and Sleeping Bear Dunes, all in Michigan; Fire Island, New York; Cape Flattery and Leadbetter Point, in the State of Washington; Mosquito Lagoon, Florida; Pigeon Point, Minnesota; Debidue Island and Kiawah Island in South Carolina; Popham-St. John, Maine; Parramore Island, Virginia; and Smith Island, North Carolina. Senator Moss of Utah has added an amendment to this bill to provide for a study of Great Salt Lake leading up to some form of preservation for that remnant of glacial Lake Bonneville.

Once Again, The Wilderness

WITHOUT intention of treating a serious subject lightly, some people have suggested that future bills looking toward the establishment of a national wilderness system within our national forests, national parks, and national wildlife and game ranges be prefaced by Shakespeare's well-known line in *King Henry V*: "Once more unto the breach, dear friends, once more . . ."

During the course of the past five years, many different bills have been submitted to the Congress for the purpose of securing for the American people the "benefits of an enduring resource of wilderness." Not one of them has been passed as yet. Over the years, the bills have been revised to meet the objections of the National Forest Service, the National Park Service, lumber interests, mining interests, Chambers of Commerce, cattlemen, sheepmen, conservationists, and many others; all told, as incompatible a group of bedfellows as could gather under a single roof.

The new members of the Eighty-seventh Congress had barely become familiar with their surroundings before Senator Clinton Anderson of New Mexico, in behalf of himself and no fewer than thirteen other conservation-conscious Senators, had introduced *S.174*, a wilderness bill. At the time these lines were written, seven Congressmen ha also introduced their own wildernes bills into the House. The general objective of all the bills: to establish an define some measure of congressiona protection for outstanding wildernes tracts within the areas under the jurisdiction of various Federal agencies. U to the present time, the classificatio and management of such areas has bee a matter of administrative decision with in the various agencies concerned.

Many conservation people think tha Congress has now gone as far as it ca in meeting the objections of the man interests involved, and that any furthe watering will result in a downrigh meaningless piece of legislation.

Saline Water Conversion

ONE needs to be a little more tha middle-aged to recall the tim when adjectives like "inexhaustible" o "limitless" were still applied to many o the natural resources of America. Th kind of descriptive exuberance is seldo heard today, especially in regard to th nation's supply of a most vital mineral water—clean, pure water.

Statistical projections of the nation water needs—even into the reasonabl near future—tell a crystal-clear story we must either clean up and make us ble the floods of sadly polluted wate that return to the sea every day, or w must demineralize and use the water the sea itself. Long-term water-use pr jections indicate that we will probab have to resort to both solutions.

For these reasons, the American pu lic will hear more and more about a office in the Department of the Interi that has only lately emerged from o scurity—the Office of Saline Wate until recently directed by Dr. A. Miller, now by Charles F. MacGowa In 1952, Congress authorized the Secr tary of the Interior to conduct researc and technical work on the developme of means for producing fresh water fro salt or brackish water; with little pu licity and a minuscule budget, the Offi of Saline Water tackled the formidab problems of large-scale water conversio

As a result of the Office's researche saline water conversion is economical feasible today in areas of relatively hi water cost; in the near future, it w very likely compete with orthodox wat systems. A milestone was passed in 19 when the city of Coalinga, California high-cost water area—installed a demi eralization unit to obtain its water su plies from brackish water. Since the several other hard-pressed cities ha either installed, or have announced tentions of installing, saline water co version plants; most recent was the c of St. Thomas, in the Virgin Islan which will build a plant to supply citizens with a daily average of 250,0 allons of pure, fresh water "manufac- ıred" from sea water.

In the Eighty-seventh Congress, seven ills have been introduced in both House nd Senate to provide for expansion of ıe saline water conversion program.

In postscript, it may be pointed out ıat saline water conversion techniques re also adaptable to the purification of olluted fresh water, a fact that carries ırge implications for water-starved cit- s located along some of the nation's reat—and greatly polluted—rivers.

Arctic Wildlife Range

CIENTISTS, conservation workers, and many an unclassified "man on the reet" will not soon forget that former cretary of the Interior, Fred A. Sea- n. in the closing days of his tenure office, established the long-hoped-for rctic National Wildlife Range, some 00.000 acres of magnificent wilder- ss above the Arctic Circle in north- stern Alaska. With almost the same roke of the pen he also created two her important wildlife ranges in that ıge new state; the Kuskokwim, nearly 00.000 acres on the delta of the Kus- kwim and Yukon Rivers, in western aska, and the Izembek, 415.000 acres the north side of the peninsula.

The new Arctic Wildlife Range is arly twice the size of the State of New rsey, and includes a portion of the ugh and desolate Brooks Range of rthernmost Alaska, as well as a vast reage of plains, tundra, and Arctic ore line. In sum total, it is the habitat such large mammals as the polar, ack, and Arctic grizzly hears, Stone ribou, Dall sheep, and Alaska moose, well as smaller mammals such as wolf, wolverine, ermine, otter, lynx, d beaver. Scientists and conservation- both have pointed out the urgent ed for reasonable protection of big me mammals in this once-inaccessible gion. Some of these mammals have en threatened with extinction through essive destruction by hunters.

The Kuskokwim Wildlife Range in- ıdes what is probably the greatest mi- ıtory waterfowl breeding area on the rth American continent. It is mostly rsh and tundra, and largely uninhab- d by humans, although it supports considerable population of red and ite foxes, mink, otter, and muskrat. e Izembek Range, habitat of the ɔwn bear and the Stone caribou, is ıska's most important concentration nt for migrating waterfowl.

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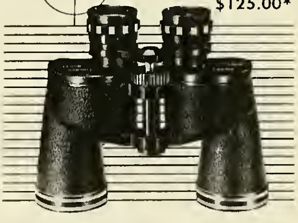

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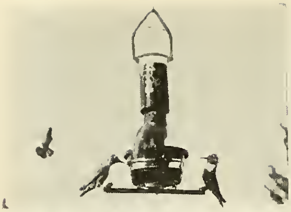

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As a matter of interest, the difference between a national wildlife range and a national wildlife refuge is one of the degree to which commercial exploitation is permissible. Oil and gas exploration and mineral leasing may be allowed within a wildlife range; ordinarily such activities are not permitted in a wildlife refuge.

The Rainbow Dilemma

THE appointment of Representative Stewart L. Udall to the post of Secretary of the Interior, vacated by the outgoing Eisenhower administration's able Fred A. Seaton, was received by conservationists and their leaders with nearly unanimous satisfaction. It was widely felt that former Secretary Seaton's accomplishments in the fields of conservation and preservation were very considerable, in view of the somewhat less than ardent approach to those subjects taken by both the departing administration and the Eighty-sixth Congress.

One of the headaches inherited by the new Secretary of the Interior from the Eisenhower regime and the Eighty-sixth Congress is the vexing Rainbow Bridge controversy. Rainbow Bridge National Monument is a relatively obscure area of a mere 160 acres in the wild and broken canyon country of southern Utah—an area often called the nation's last bit of true western frontier. Fifty-odd years have elapsed since the Monument was established by a 1910 proclamation by President Taft to preserve the world's largest natural bridge. Since then a total of only about 12,000 strong-legged visitors have made the arduous, and sometimes dangerous, trek through the vast jumble of canyon and naked sandstone "slickrock" of the San Juan River country to feast their eyes and cameras on the stone rainbow.

When the Upper Colorado River Storage and Development Act was passed by Congress in 1956, conservationists made sure that it contained a commitment for the protection of Rainbow Bridge which is hidden away in a canyon of tributary of the Colorado River, from th encroachment of the water of Lake Powell, to be impounded behind the hug Glen Canyon Dam on the Colorado. Construction work on the Glen Canyon project commenced in earnest last year but conservationists were angered an alarmed by the refusal of the Eighty sixth Congress to make good on the intent expressed by the earlier session. refused to appropriate any money at a for protective devices to prevent th monument from being flooded.

The conservationists have taken the troubles to Secretary Udall, who, inc dentally, is among the very few Ame icans—other than American Indians who have visited the Bridge. Secretar Udall is sympathetic, although not co vinced that a water pool beneath Rai bow Bridge would damage it, and he h included an item of ten million dolla in his Interior budget for some form protection. Time alone will tell wheth the money will be appropriated by th Eighty-seventh Congress. Best guess: will not be, and one of the cornerston of national park policy—which calls f the preservation of just such areas a natural and undisturbed condition will have been seriously undermined.

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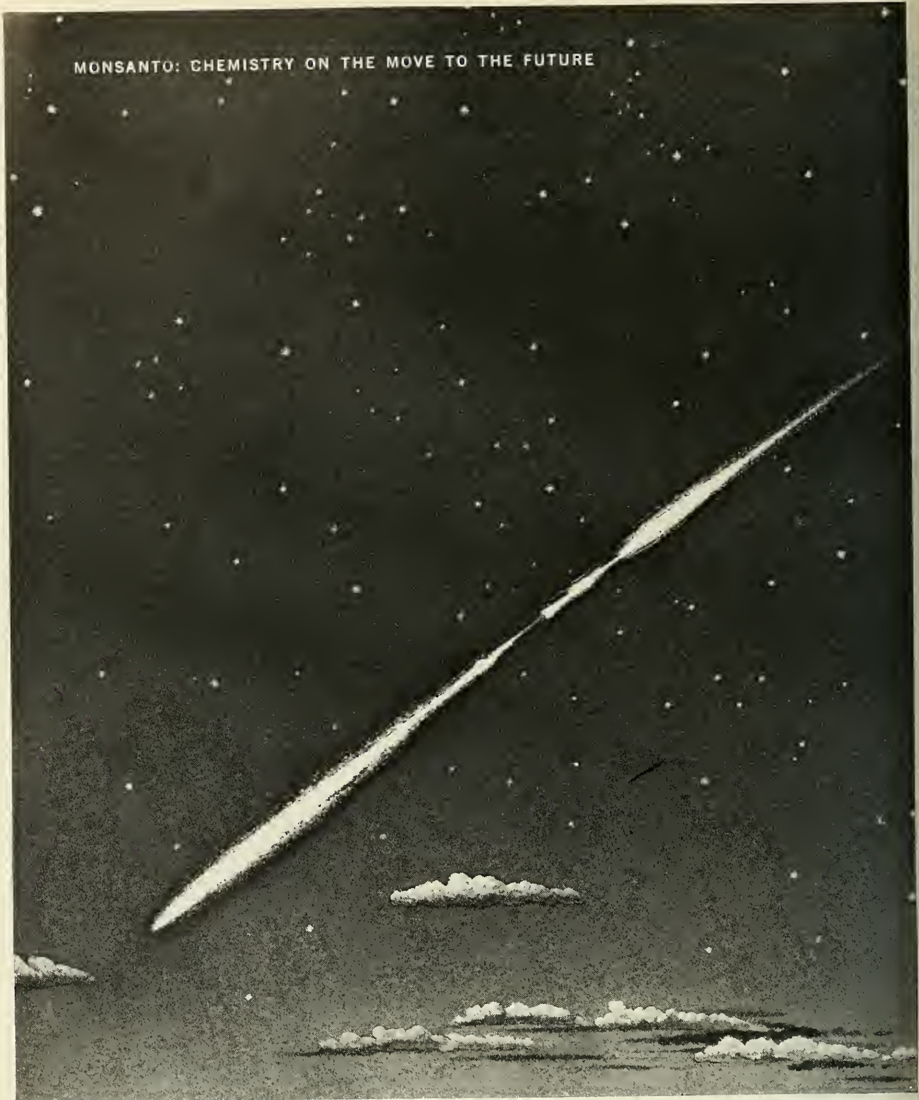
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COVER: This bumblebee was photographed by Dr. Alexander B. Klots, who Professor of Biology at City College, New York, and Research Associate The American Museum. Despite the ubiquity of these insects, it is only in rece years that the mechanics of their flight has been studied. This is largely becaus their small size precluded such work until the late nineteenth century broug developments in photography and various other specialized instruments. Inte sive experimentation now has formed a basis for aerodynamic theories an muscle analysis, discussed by Dr. J. W. S. Pringle, beginning on page 2

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MUSEUM MEMO

By W. Douglas Burden

HE UNITED STATES FOREST SERVICE has established a definition of a wilderness as any area of not less than e thousand acres with no road through it—an area, in ner words, that a jeep cannot rattle through.

By this definition, only two per cent of the land of the rty-eight States (excluding Alaska and Hawaii) can still designated as wilderness. And, even in these dwindling nnants, there is pressure for yet more paved roads. If ery town had a town forest, a section of wild land witht a road, where shrub, swamp, pond, trees, and all wild e, including predators, were left undisturbed—a place ere those in need could revive their spirits by contact h the sources of life—it would be a boon to our race, for ny people need the woods far more than they realize. t the knowledge that wild country is there, close at hand, 1 be a balm to frayed nerves. Between man and nature re is a deep affinity. Though mysterious in quality, its estence cannot be denied. A return to wilderness is tranility regained; love of the wilders brings exultation.

But it is not just the affinity been man and nature that is imptant, for man craves challenge. ne of the greatest experiences life involve struggle with the ements. It is good to get soaked ough and frozen and half-starved l exhausted and even lost, for e are the common experiences man's past. They are infinitely re important than protection and urity, for man is a battling mal. Our spirit needs primitive tention against wind and cold storm and tide. Above all, we need it when young.

ly Vermont farm land had been badly mutilated by truction of timber, erosion of the topsoil, and drying of springs. It will be a long time before nature and per handling can restore the good earth to full health productivity. But it is on its way back. How fine it was other day to see a coyote stalk across one of my fields. to watch a fox circling some Canada geese that were pared to give him battle. How much better still, one ht, when in a blizzard I came up close to a bobcat that killed three of my sheep. The farm suddenly seemed derfully wild. Thank God for our predators—those that have the wit to survive against every machination of . The balance of nature needs them. Man needs them. They add something that nothing else can provide—they make a place *feel* wild. Let us not seek their destruction.

Why does man wish to trap every last otter and mink and lynx and wolf and mountain lion and wolverine? What a pity that so many should fail to see the necessity of their existence. Usually, this is a failure to appreciate the full round orderliness of our natural world. What would a jungle be without a jaguar or leopard!

IN the last analysis, the wilderness is disappearing because of the sheer pressure of too many people. Yet, in the beginning, man lived in the wilderness. Man's need for the wilderness goes back to the deepest core of his being. Fortunate are those who have discovered its infinite riches. Days in the open go on and on. They are measureless and filled with time. There is hardly a beginning or an ending. The greatest of all gardens are the gardens of the wild. They cost not a penny to maintain and they are the most beautiful. If we sit alone in the wilderness and look and listen and brood, after a while we merge with it. The desire to be "in tune with the universe" springs from our innermost being. The sense of belonging adds to our peace of mind. To acquire the wisdom to live in harmony with nature is our greatest goal. It transcends all other values.

Wilderness is a temple that cannot be rebuilt like a bombed-out cathedral. It is infinitely complex. Every part is interwoven on another. From the prowling predator to the enzymes in the soil, the ecological relationships are subtle and deep—yet so carefully balanced that the same ones may never be restored. To top a rise and find vast stretches of prairie inhabited only by the wild animals that belong to it—this is treasure unsurpassed. But it is treasure that we squander, for man rarely values what he has. It is only when it is gone that he begins to sense the depth of his loss.

We need a million million voices—not crying *in* the wilderness but crying to preserve it. Let us save every swamp and bog, forest and desert, canyon and mountain fastness that we can. It is the great garden of inspiration for our future. It is the elemental heritage of the human race. Let us save wilderness everywhere. It is our birthright.

"How lightly might this earth bear Man forever!"

An outstanding amateur naturalist, Douglas Burden has been closely associated with THE AMERICAN MUSEUM for almost fifty years—first as a young collector when he left college, and later as an organizer of expeditions to many parts of the world, as a patron, and as a Trustee since 1926. Last year, Mr. Burden's memoirs, entitled *Look to The Wilderness*, were published by Little, Brown and Company and the work has received critical acclaim. Because his closing pages contain an appeal for goals that are shared by all of us at the Museum, we have excerpted his words for this memo.

ALEXANDER M. WHITE
President

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Reviews

Three views of the world of fishes

By James Atz

Living Fishes of the World, by Earl S. Herald. *Doubleday & Co., $12.50; 304 pp., illus.* Guide to Marine Fishes, by Alfred Perlmutter. *New York University Press, $6.50; 431 pp., illus.* Why Fish Bite and Why They Don't, by James R. Westman. *Prentice-Hall, Inc., $3.95; 211 pp., illus.*

Ichthyophiles are a motley crew. In fact, any politician who successfully put to use the rallying cry, "Fish lovers of the world, unite!" would find that he had acquired a constituency with nothing in common save devotion to some aspect of the finny tribe. Even this particular focusing of attention on a single type of animal is mutually exclusive in many instances. Fishermen frequently have little interest in fish beyond catching them, and even here the points of view of sport and commercial fishermen are poles apart. Fish fanciers live in a world bounded by their home aquariums, while ichthyophagous epicures may hardly recognize a fish when not on a platter. Finally, there are those idealists who love the fish for itself, a variegated company that includes skin divers and other amateur naturalists, professional ichthyologists—and even curators of public aquariums!

Sheer size would account for some of the group's heterogeneity. In the United States alone, there are more than 29 million anglers, while an additional half-million people are associated with the commercial fisheries. Perhaps ten million American families keep goldfish or various "tropicals" as pets. Although the average American eats only a little more than ten pounds of fish during the course of a year (as compared with the 110 pounds consumed by a Javanese, for example), the national total—nearly 900,000 tons of edible fish—is hardly a quantity to be ignored. With the price of fish what it is today, taste, rather than economy, must account for the purchase of a good deal of this tonnage.

Such numbers of people with a more-than-nodding acquaintance with fish would seem to warrant publication of a fair selection of books devoted to these creatures; but in truth, the number of really satisfactory popular fish volumes in English can be counted on the fingers of one hand—and I am excepting, here, only the dozen or so handbooks that deal adequately with the fishes of some part of the United States and make no pretense of furnishing a well-balanced account of fish life. Narrowness of interest may limit the market somewhat, but what better way to broaden these horizons than with a few attractive and well-rounded volumes? It is, therefore, an unusual pleasure to be able to introduce to Natural History's readers three new titles—all of them noteworthy additions to the meager but select list of topflight, popular books on ichthyology.

Earl Herald faced a formidable task in writing, for the layman, a single volume that covers all the world's living fishes. Present estimates put the number of species at some 30,000—more than all the different kinds of mammals, birds, reptiles and amphibians combined. Moreover, the bony fishes themselves show a greater variety of structure than any other comparable group of backboned animals, and one must also consider the completely different boneless sharks and rays, and the jawless lampreys and hagfishes. Altogether, fishes form a bewildering array, even to the specialist. As the world's authority on the classification of seahorses and pipefishes on the one hand, and as the organizer and host of an award-winning television show, "Science in Action," on the other, Dr. Herald fully realized how difficult it would be to transform pages upon pages of technical description into something understandable and interesting to the intelligent but untrained reader. Nevertheless, he did not try to evade the problem by ignoring the less well-known groups of fishes, the ones about which practically nothing is known except external anatomy and geographical distribution. He has accordingly treated all of the orders and most of the families of living fishes, and he has produced what is by far the most complete survey of them ever made in English, and probably in any language.

Because of his extensive experience with fish in captivity and in nature, both as head of San Francisco's renowned Steinhart Aquarium and as ichthyologist and diver-collector on several expeditions, Dr. Herald was able to enliven his text with exciting and informative personal anecdotes. *Living Fishes of th World* will not, however, be perused from cover to cover very often. It is, rather, a reference work and, as such, volume to be browsed through repeatedly. Many pleasant hours could be spen reading about this or that group o fishes and looking at the associated illustrations. It took a world-wide search t find all the outstanding black-and-whit and color photographs that so handsomely illustrate the book. Without question, they comprise the finest collectio of fish pictures ever assembled.

Despite their tremendous diversity many fishes at first glance look surprisingly alike. A trained eye is neede to spot the essential anatomical differences that distinguish similar species and there are some fishes so nearly alik that experts have to look twice befor committing themselves. No one, no ma ter how expert, could ever hope to lear to recognize more than a small propo tion of the thousands of different specie Therefore, to help one another identif fishes with which they have had no pr vious experience, fish taxonomists co struct what are called "keys." Thes keys work reasonably well for the ta onomists, but the amateur who tries use them soon finds himself hopeless entangled with strange terms and co cepts. The few keys that have been sp cifically written for non-ichthyologis have been either quite limited in scop or not entirely successful, mostly b cause they were no more than mod fications of keys extracted from th technical literature.

For twenty-two years, Alfred Pe mutter worked variously for the U. Fish and Wildlife Service and the Bu eau of Marine Fisheries of New Yo State's Conservation Department. Ma times he heard fishermen lament the la of a "practical" key, as they put it, th would enable them to identify unusu specimens that came their way. Fish

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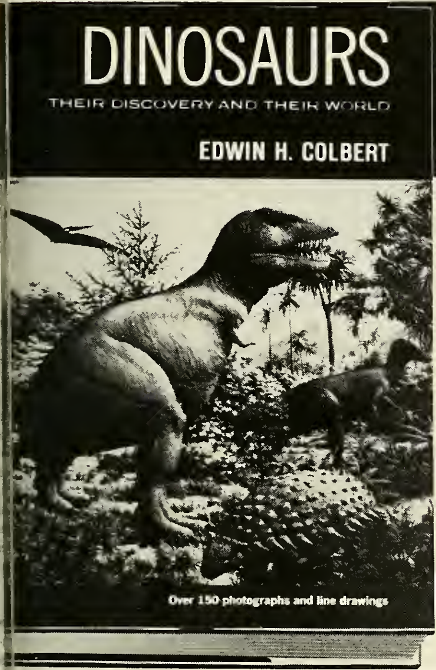
Dr. Atz is the Associate Curator of the New York Zoological Society's Aquarium, located at Coney Island.



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men, both sport and commercial, as wel
as amateur naturalists with a marin
bent, are at least as common along ou
Middle Atlantic seaboard as anywher
else, and the need for such a key in thi
area is correspondingly great. *Guide t*
Marine Fishes is Dr. Perlmutter's an
swer to that need. The key he has de
vised departs distinctly from all its pred
ecessors. It is entirely artificial—that is
it does not try in any way to reflect th
natural relationships among the fishes
but arranges them solely for the con
venience of the user. This is, in the re
viewer's opinion, a *sine qua non* of an
truly non-technical key. The fishes ar
grouped according to external struc
tures that are easily seen, and each iter
is identified by an illustration. For ex
ample, when the key states, "Two dorsa
fins," the opposite page carries an ou
line drawing of one of the fish with a
rows pointing to its dorsal fins. Below
the contrasting character—in this cas
"Three dorsal fins"—similarly illu
trated. At every step, the user will fin
that the choice he must make is clea
because both categories are illustrate
the one to which his fish does *not* belon
as well as the one to which it does.

By means of this remarkably straig
forward key, a person with no biologi
training whatever can identify any o
260 species of fishes most comm
found along the Atlantic coast be
Cape Cod and Cape Hatteras. So
the rarer migrants and strays into
region have not been included, but th
are not encountered often enough
cause serious confusion. Since anyo
who goes to the trouble of identifying
fish presumably would like to lea
something about it, Dr. Perlmutter h
provided a brief account for each s
cies—color, distribution, size, econom
importance, and general informatio
the latter including notes on its l
history, behavior, and ecology. But t
raison d'être of this book is its uniq
key, which should be the progenitor o
whole series of popular keys of fish
from other parts of the world.

ANGLING is much more of an art th
a science. If and when the reve
becomes true, fishing will probably
come a much less popular sport than
is today. Nevertheless, there is plenty
room for the application of scient
principles and data without the slight
risk of taking any of the romance out
fishing for fun. James Westman belie
that angling ought to be an art ba
upon a science, but he is aware that
angling, the art is emphasized almost
the exclusion of the science. *Why F*
Bite and Why They Don't is his atter
to inject some science into sport fishi
Dr. Westman has been closely connec
with the marine and fresh-water fis
ies of New York and New Jersey
many years. He knows angling and

not only from the point of view of onservation official and fisheries bi-st. but from the viewpoint of an in-as well. He has utilized the findings ientists, including himself, to in-e his catch: a number of the tips book were developed in this way.

e problem of getting fish to bite is tially a behavioral one. Very few iments directly applicable to fish-conditions have been performed. ehaviorists have accumulated large nts of information, the proper in-etation of which might shed consid-e light on the feeding reactions of Fo the best of my knowledge, most s material has never been analyzed. eason being that a great deal of it een published only in German. Dr. nan hits only the high spots in his but provocative presentation. There lence that under certain conditions isory stimulation, a fish *must* bite. implication is plain: the type of nd the way it is presented is more tant than whether the fish is "hun-or "in a feeding mood."

onsiderable number of experiments also shown that fish act as if they hate preferences for certain colors terns and, further, that it is dif-i impossible to change such a e by means of training with punishment. Again, the impli-the importance of lure design ous. As to exactly what fish are le of seeing, hearing, smelling, and e, the more we learn, the more we l at their extreme sensitivity. For ice, young salmon can smell an or-chemical at a dilution of one ounce) million million gallons of water 10^{13} gal.), and other fish can de-rise in water temperature of less a tenth of a degree. Fish can learn quickly, too. Dr. Westman found argemouth bass would disregard a ninnow attached to a hook and r after one or two bad experiences, ntinue to snap up free minnows.

y Fish Bite and Why They Don't vritten for anglers. Besides the be-r of fish, Westman discusses the in-e of the seasons on fish and their ability, and describes fishing tech-s of all sorts in detail. He con-s with a chapter on the preserva-f fresh fish and the proper cooking h. The author has a lucid way of ht, an easygoing style, and a lively of humor. Like Melville, he believes "meditation and water are wedded er" and he appreciates the contem-e as well as the competitive as-of angling. From the reviewer's of view, the most important thing Westman's book is the good word its in for the scientific approach. rs are really not in need of it any than the rest of us, but—as the rest they certainly could use it.

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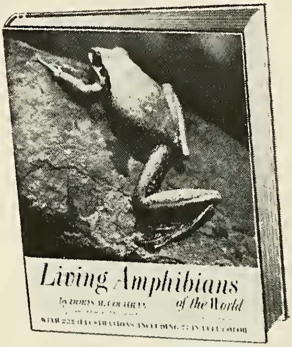

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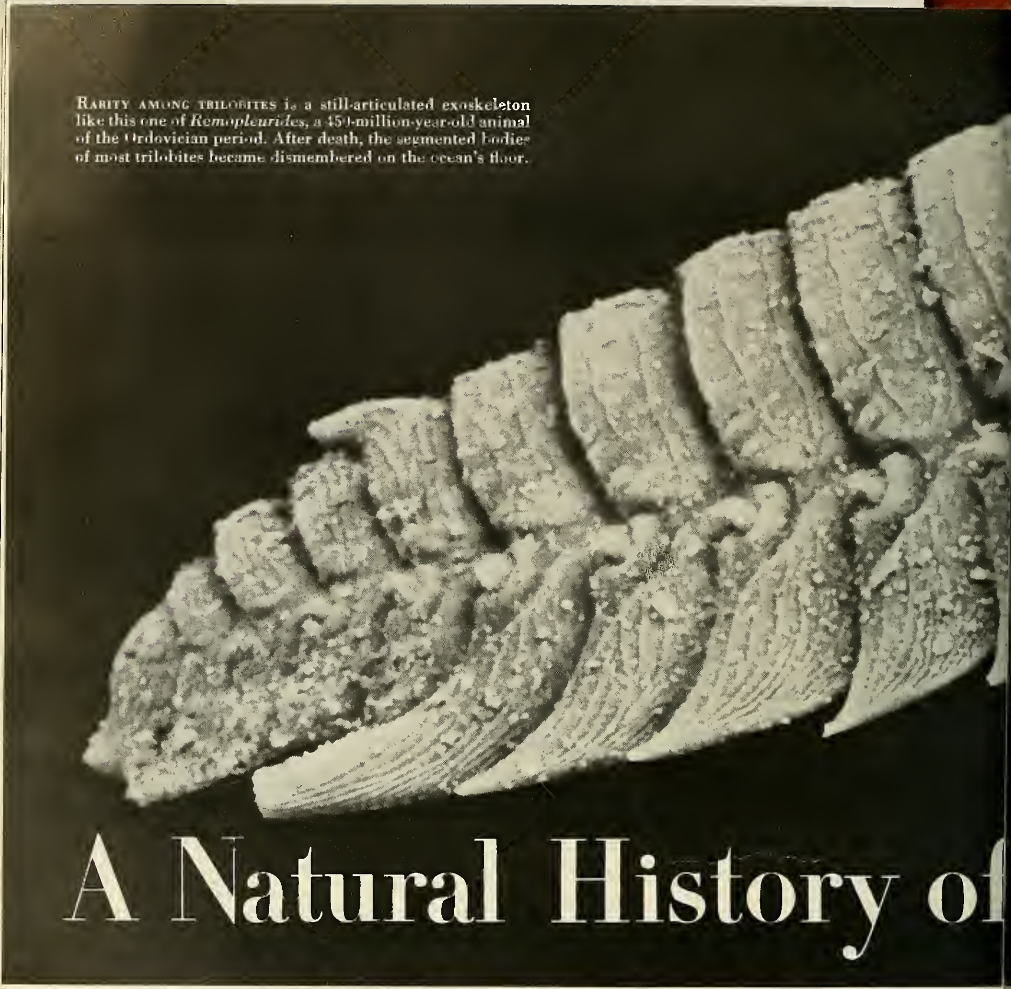


Rarity among trilobites is a still-articulated exoskeleton like this one of *Remopleurides*, a 450-million-year-old animal of the Ordovician period. After death, the segmented bodies of most trilobites became dismembered on the ocean's floor.

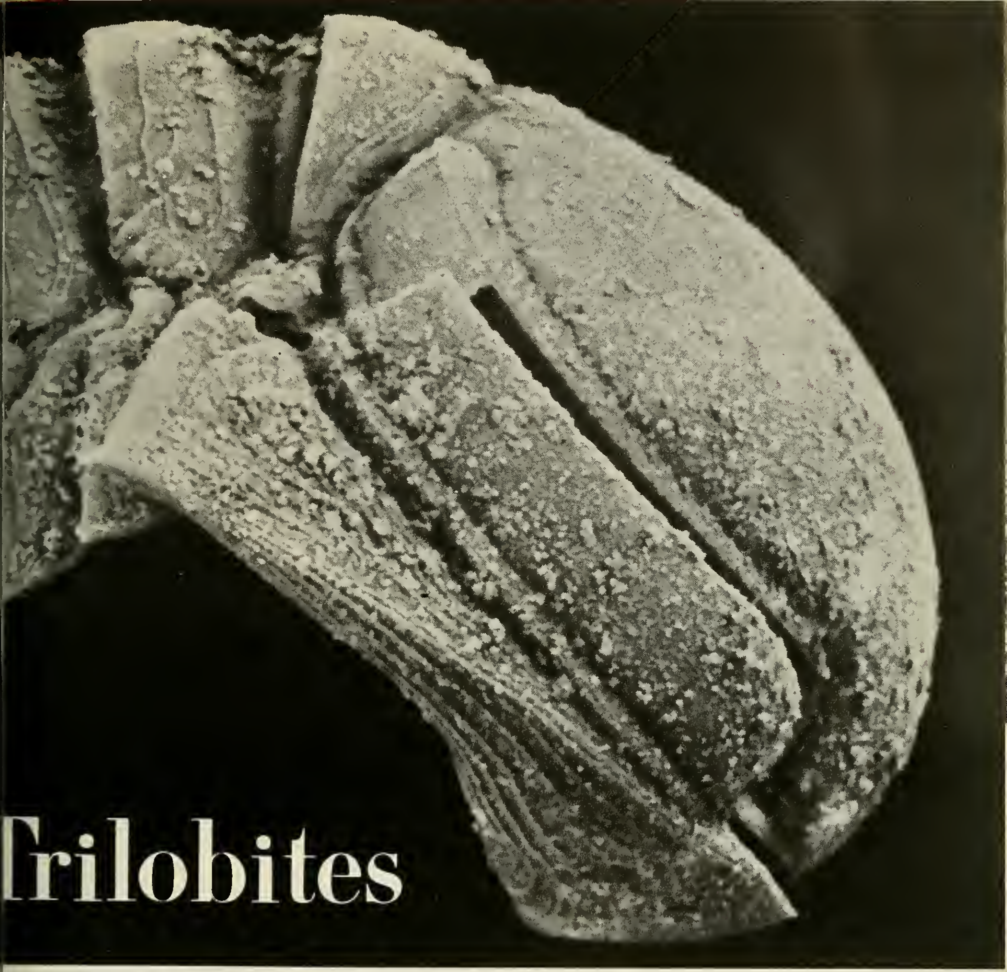
A Natural History of

The fossil evidence allows deductions about these extinct animals' behavior

By H. B. Whittington

Trilobites are arthropods, one class of a phylum of invertebrate, segmented animals with jointed legs that contains among its living representatives such diverse forms as insects, spiders, centipedes, crabs, and lobsters. They are found in the oldest rocks of the Paleozoic era, at the beginning of the Cambrian period, some 600 million years ago. These animals, abundant in the early part of the Paleozoic era, decreased during the middle part of that era, and were even fewer in its younger rocks. The last survivors are found toward the end of the Paleozoic, about 250 million years ago. Trilobite fossils occur in a very wide variety of sediments—sands, silts, muds, and limestones. The other types of fossils found with them suggest that these sediments were laid down in relatively shallow, marine waters.

In the process of preservation, the original mineral matter in the trilobite's shell may be preserved, or tl re may be some addition to—or repl ement of—this matter. Or the orig al material may be dissolved away together after burial and consolida on of the rock, leaving only an impres on or mold of the shell. Study of the ll-preserved shells of trilobites sh ws that the animal's body comprise a head region, followed by a thora (a series of segments that articulated th each other), and a tail. The tail re on is formed by the fusion of several gments like those in the thorax; it ay be smaller, equal in size, or larger an the head. The shell covered the ck of the body, and, on the underside extended inward only a short dist ce from the margin. Since it is ou de the body, it is called an exoskel on.



Trilobites

Fhe trilobite's body was bilaterally nmetrical; it had a raised region ending lengthwise down the middle l was flattened or downcurved on h side. It is this three-lobed form t prompted the name Trilobita for se animals. The raised middle ren of the head was very prominent some species and bore deep, transse grooves reflecting the segmenta-n. On each side of the head were sed eye lobes. Across these eye lobes l around the front of the head ran impressed line, the suture line, ng which the shell split at the time en the animal molted.

Some trilobites are preserved with body stretched out horizontally; in ers, it is rolled up so that the tail ucked tightly in beneath the head. There were articulating devices between the movable parts of the exoskeleton, and the outer parts of the thoracic segments were beveled and could slide over one another. The animal could only roll or unroll in the vertical plane, however. Its raised middle region and the horizontal adjacent parts of the segments make it evident that no side-to-side curving of the body in the horizontal plane was possible.

Complete exoskeletons are the exception in fossil finds. It is more common to find only parts such as heads, individual thoracic segments, and tails, disarticulated from each other. The head itself is often separated into parts along the suture line.

Among the best-preserved trilobite shells known are some remarkable ones from Virginia (illustration, *above*). After burial in lime mud (which later became limestone), these shells were replaced by minutely granular quartz in a manner that preserved all the details with extraordinary fidelity. When blocks of these limestones—they are Ordovician in age—are placed in dilute hydrochloric acid, the limestone is dissolved, but the replaced trilobite shells are unaffected and so can be freed from the enclosing rock without damage. The shells of any one species are not all of similar size, but

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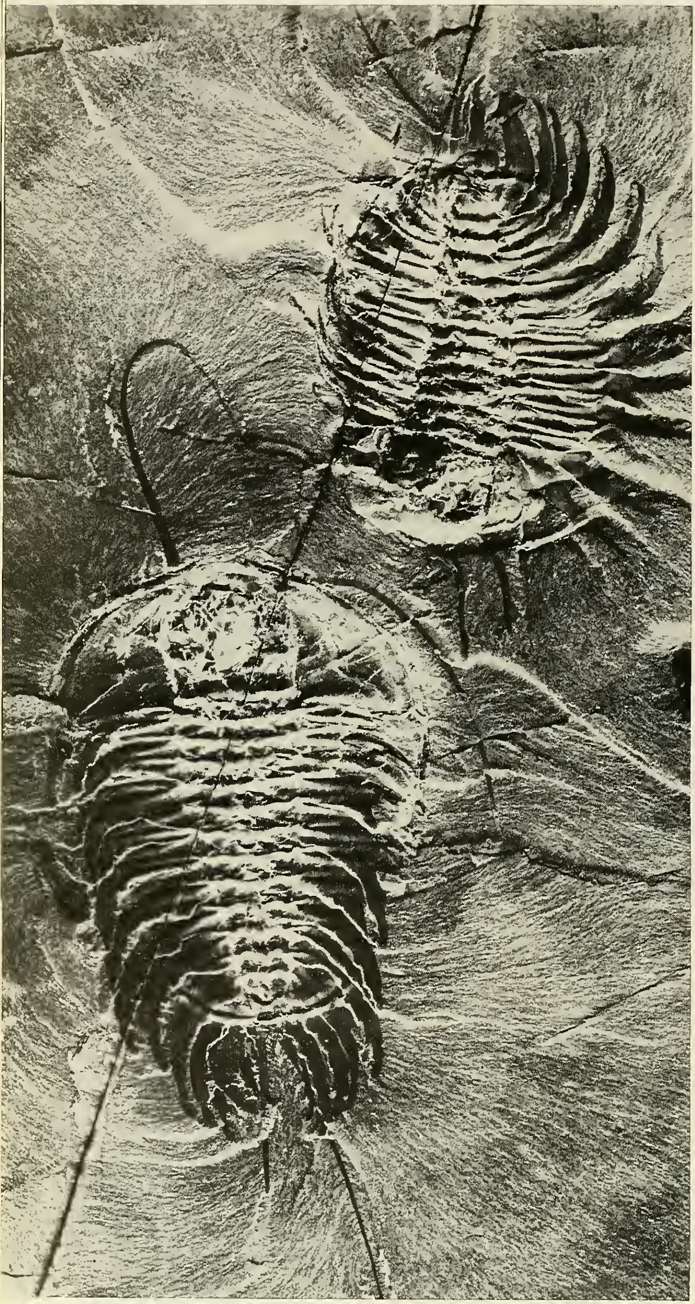
DR. WHITTINGTON, who specializes in the paleontology of the Ordovician, works at Harvard as a staff member of the Museum of Comparative Zoology.



Trilobites such as this *Olenoides* pair, with appendages visible as a thin film extending beyond the body, come from the Burgess Shale of British Columbia.

form a graduated series. This seri
gives a record of the animals' she
growth—which took place by period
molting—from that first formed, whic
was less than one millimeter in lengt
onward. Articulated skeletons, lik
those of *Cryptolithus* and of *Rem*
pleurides, are extremely rare in the
particular limestones, presumably b
cause almost all the shells were di
membered as the dead animals drift
about on the sea bottom. Thus, si
series are usually available only f
individual parts of the exoskeleto
for example, the part of the head b
tween the suture lines. Such a seri
exhibits the changes that took place
outline and convexity, as well as t
reduction in relative size of the spine

In the process of a trilobite's growt
new segments of the thorax were dev
oped in the tail portion. As they b
came fully formed at the front edg
they were released to become free
jointed between the head and tail. T
number of segments thus formed
characteristic for each trilobite sp
cies. Exoskeletons that include si
series have also been obtained fr
limestones in Utah and Nevada, whe
they are preserved also by silicifi
tion. From other areas and countri
in shales and siltstones, have come si
series of articulated exoskeletons,
notable example being those describ
from Czechoslovakia more than a h
dred years ago by J. Barrande.

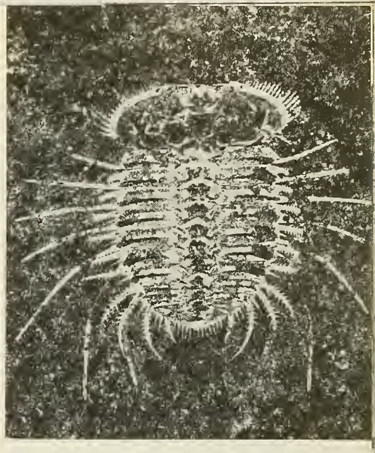
It is extremely rare to find parts o
trilobite preserved other than t
exoskeleton. This is presumably b
cause the exoskeleton was streng
ened by secretion of mineral matt
but the covering of the antennules a
other appendages was not so re
forced. From a few localities, t
most important being in North Am
ica, remains of appendages are kno
An early discovery, announced
1876, was made by Charles D. Walc
(later the Secretary of the Smithson
Institution) in a limestone bed n
Trenton Falls, N.Y. Spurred on by
memory of the enthusiasm of Lo
Agassiz, Walcott obtained over 3,5
entire trilobites, in a few of which
appendages were preserved. Walc
cut thin sections of these specime
and demonstrated clearly that tr
bites possessed jointed appendages

A few years later, W. S. Vali
then curator of the museum at Rutg
College, picked up a loose piece
rock near Rome, N.Y., which c

tned a trilobite with appendages pre- sved by having been infilled with prite. A patient eight-year search re- sted in the discovery in 1892 of the drk shale layer, less than one centi- nter thick, from which Valiant's lse specimen had come. The forma- tn contained hundreds of similar scimens. Delicate excavations of tse fossils were made by Professor E. Beecher of Yale University, but h died while still working on a draw- of one of his remarkable prepara- tns. His student, Percy E. Raymond, tk up the work and wrote an epic nnograph concerned with the nature trilobite appendages.

LONG before this monograph was completed, Walcott had made an- er sensational discovery, this time the Burgess Shale—a formation of ddle Cambrian age — near Field, tish Columbia. A great variety of hropods are preserved in these sles. including trilobites with the pendages actually visible as a thin sery film extending out beyond the rgins of the exoskeleton.

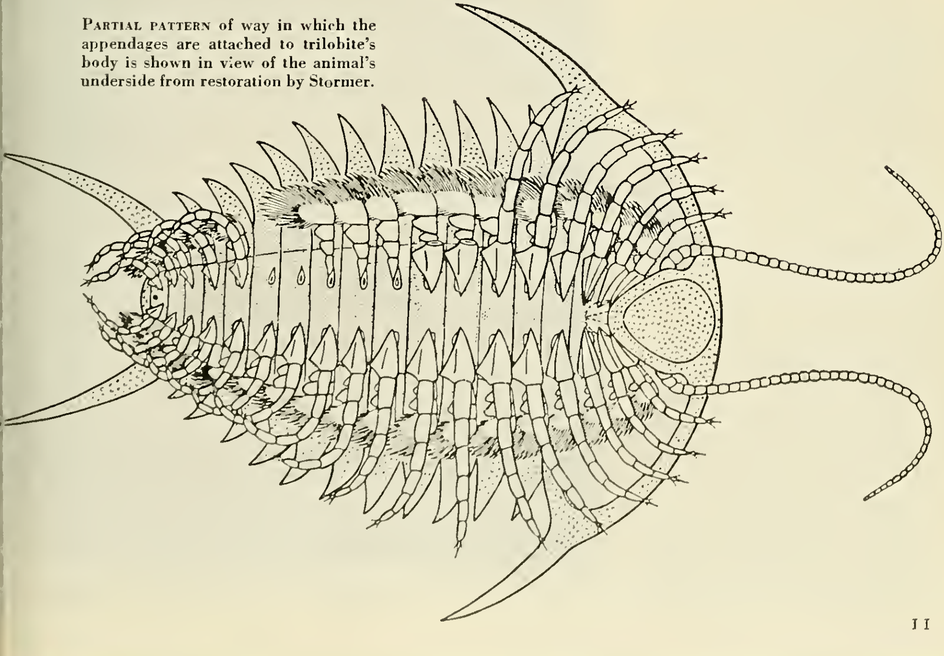
No finds of comparable richness e been made since these early days, l advances in our knowledge have ne from the application of more re- ed techniques. An example of such an investigation is that made by Professor Leif Stormer of the University of Oslo, who came to the United States in 1931 and worked with fragments of Walcott's original material from Trenton Falls. Stormer ground a series of sections. parallel to each other and a small distance apart, through an enrolled specimen. An enlarged drawing of each section was made, and each drawing was traced on a sheet of wax. The thickness of the wax sheets was proportional to the enlargement of the drawing and to the distance between successive sections. Each outlined wax sheet was then cut out and the sheets put together to form an enlarged model of the original specimen. The model gives an idea of the great amount of detailed information provided by Stormer's work. This new knowledge, combined with a restudy of all previously discovered material, has resulted in a major advance in our knowledge of trilobites.

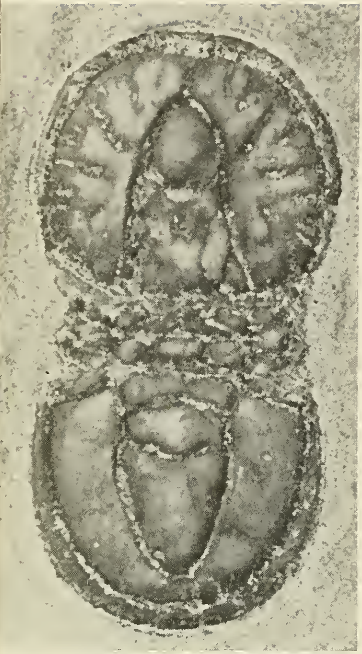


Appendages of ***Miraspis*** **are visible in this Czech specimen of Silurian date.**

The head of this model shows the large plate (or hypostome), which lay underneath the middle region, together with parts of the appendages beside this plate. Most students of trilobites today believe that the animal's mouth lay just inside the posterior edge of the hypostome, and that the stomach and other organs were enclosed in the capsule formed by the hypostome and the middle part of the head. The alimentary canal then extended back beneath the middle part of the body, terminating in an anus at the posterior tip. Stormer's reconstruction of the underside of the body shows an enclosing membrane and a pair of similar appendages on each segment. Each appendage consists of a jointed walking leg with bristles at the tip. From near the base of the appendage rises a jointed branch that bears many fine

Partial pattern of way in which the appendages are attached to trilobite's body is shown in view of the animal's underside from restoration by Stormer.





Two thoracic segments divided equal-sized head and tail of *Ptychagnostus.*

filaments. Under the head are four pairs of appendages; in front of them are the long, jointed antennules.

All investigations have shown that the trilobite's appendages were similar on each segment, and that none bore a claw or pincer for grasping and tearing food and passing it to the mouth. Trilobites probably fed, therefore, on minute organic particles suspended in the water or enclosed in the sediment of the sea bottom, this material being brought to the mouth by currents of water. The filament-bearing branches of the appendages may have been the main instruments in producing these currents. They probably also functioned as gills, and constant movement of the branches would have kept the gills bathed with fresh water.

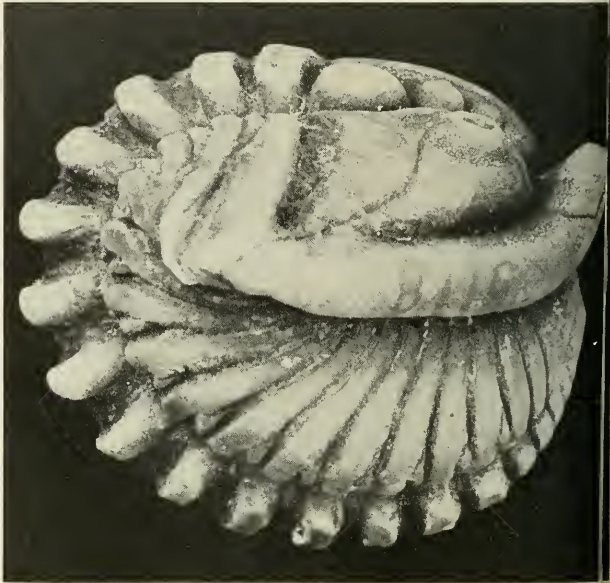
The trilobite's appendages were attached by muscles to the convex middle region of the exoskeleton. Deep furrows in this region on the head, thorax, and tail formed projections on the inside of the shell for such attachments. Trilobites with smooth shells may show dark patches, which are believed to be corresponding areas of muscle attachment. The animal must also have possessed longitudinal muscles to effect its characteristic enrollment: these were probably situated in the middle region of the body.

It has been argued that trilobites like *Isotelus* (photo, p. 17), with its wide middle region and its relatively large tail, may have used a downward and forward stroke of the tail in swimming, as does the modern lobster. The bodies of these two animals are not comparable, however: the space for powerful muscles in the thorax and tail of this species of trilobite was not so great as that in the lobster tail.

Rigidity and strength must have been important requirements of the trilobite exoskeleton, since it was the framework upon which the muscular system operated. On the outside of the shell are ridges and grooves, pits, tubercles and raised lines, incorrectly called "ornament." These served to make the shell rigid, as do sheet-iron corrugations. In well-preserved specimens, many minute openings have been observed at the tips of short spines and tubercles. These are the ends of exoskeletal canals that led to sensory hairs or from glands beneath the exoskeleton. Such canals are als
to be found disposed around the ma
gins of the exoskeleton.

The main supply of the organic pa
ticles on which trilobites fed must ha
been close to the surface of, or withi
the sediments of the sea bottom. W
may reasonably conclude, then, th
trilobites lived largely in this botto
region, swimming by means of to-an
fro movements of their appendage
and also walking on, and digging
raking in, the bottom sediments. T
antennules extended forward, explo
ing the region immediately ahead, a
the eyes, with their many small face
were well adapted to detecting mov
ment in such surroundings.

Gradually, then, a picture of t
life of these animals begins
emerge from a study of their anatom
Trilobites must have made impr
sions in the soft mud of the ancient s
bottom as they searched for food.
such impressions were later filled
by sand or silt, they might be p
served as fossil casts, projecting fr
the underside of a layer of silt or sa
now converted into rock. Just su
tracks and trails are found in Pal
zoic rocks: one sort of trail, call

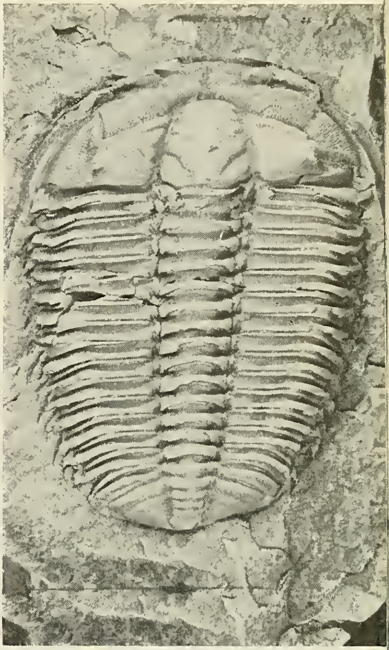


Enrolled exoskeleton of Ordovician genus, *Flexicalymene,* is seen from the side. Cup-shaped structure at top is eye, with suture line running to s e.

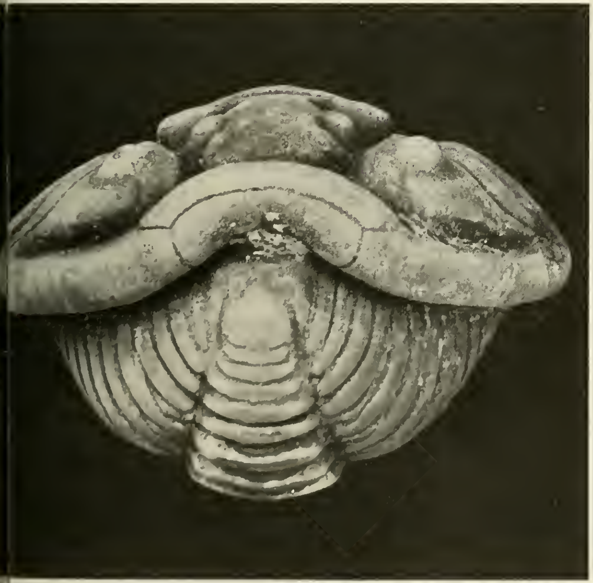
phycus, is known from many con-its. It is bilobed, with a prominent an longitudinal ridge. On each are obliquely directed ridges and ves. In one example, clear impres- are believed to be those of an al's jointed appendages.

ese trails are commensurate with bites. They may be shallow, or and pocket-like, or more or less nuous. Inward and backward ements of the walking limbs of the al could have scraped out the hollow pushing out the material in the line behind them. Impressions in ides of some of the deep hollows elieved to have been made by the s of a trilobite head and by spines thoracic segments. The trails are interpreted as shallow excava-. or perhaps even tunnels, made ilobites in the bottom sediment ey passed through it in search of Some of the deep pockets have thought of as excavations made he deposit of eggs, such as the shoe crab *Limulus* makes today. e might expect that, occasionally, ad individual trilobite would be associated with such a trail— emains of an animal that had or of one that was overwhelmed by a sudden inrush of sediments or some other catastrophe. Yet, so far, no such dramatic proof of this scientific detection seems to have been found. Thus, the interpretation of these trails, although reasonable, is not positive. In almost all cases, fossils are the remains of animals that possessed hard parts (skeletons impregnated with mineral matter) that could be preserved. Yet in these ancient seas there were, in all probability, many inhabitants that lacked such hard parts. Conceivably, some of these fossil trails are the enigmatic traces of just such soft and now vanished animals.

A different type of track, from Lower Cambrian rocks of Pakistan, has recently been described by Dr. A. Seilacher of Goethe University, Frankfurt am Main. This track, *Dimorphichnus*, is abundant on the surfaces of the sandstone layers in which the remains of trilobite shells are rare. Nevertheless, the size and nature of the track makes it probable that it was made by the tips of the appendages of a trilobite (photograph and diagram, p. 15). Dr. Seilacher considers that the animal held itself diagonally to its direction of progression, and that it dug in the walking legs on one side to make deep, short scars, while raking over the surface with the legs on the other side to form longer scraping marks. Another example of a track, from an Upper Ordovician siltstone of the Cincinnati area, may also have been made by a trilobite in motion.

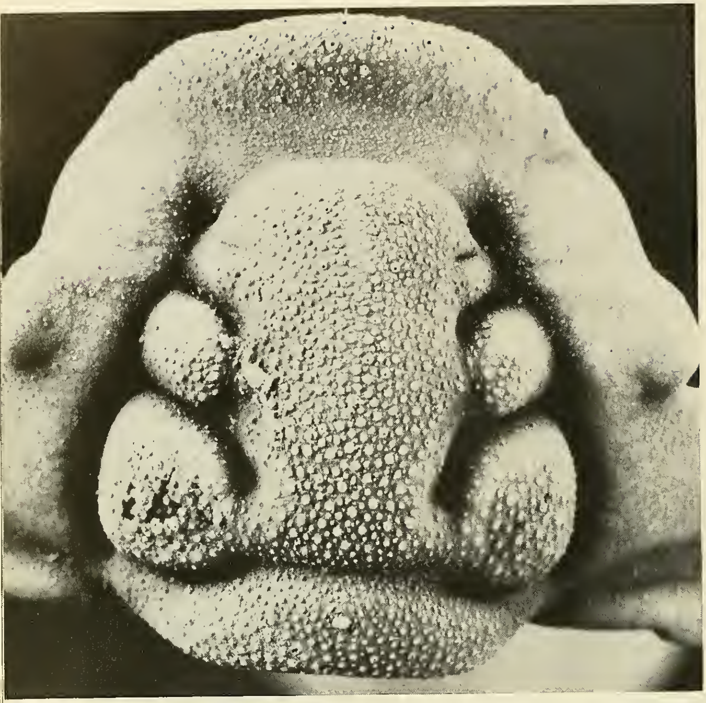


Fourteen thoracic segments and very minute tail characterized *Ptychoparia.*

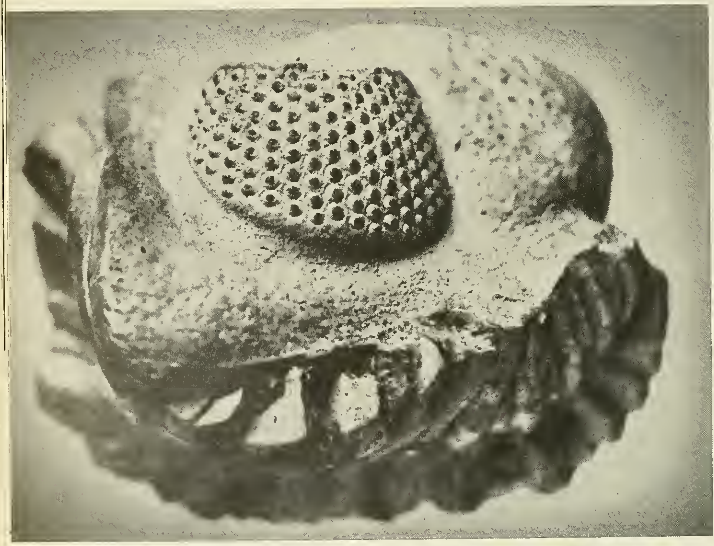


FRONT, *Flexicalymene* shows the -lobed form that prompted the name Trilobita for these animals. The shell split on suture line at molting.

Thus, compilation of all available knowledge of the trilobite body, combined with interpretations of the tracks and trails, affords a picture of how some trilobites may have lived. Those like *Isotelus*, smooth-shelled, and with the tail similar to the head in size, or like *Dipleura*, which had a narrower body and more thoracic segments, are presumed—because of their smooth, elongate form—to have burrowed into the sediments. There does not seem to be any obvious correlation between the type of exoskeleton and the habit of raking the surface of the sediments or making shallow excavations in it. Such a mode of life seems reasonable for such different trilobites as *Ptychoparia*, *Flexicalymene*, *Cryptolithus*, or *Cordania*. The broad, pitted fringe around the head of



Mid-section of this *Flexicalymene* head shows black spots on tops of tubercles. These are the openings of canals that once were occupied by sensory hairs.



Right eye surface of *Phacops*, from Devonian period, is covered with small convex facets reminiscent of those in contemporary crustaceans and insects.

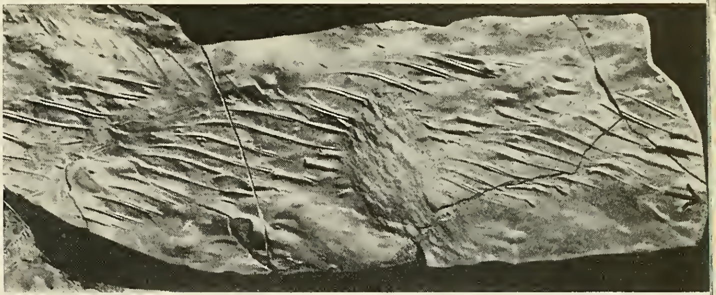
Cryptolithus and the long, backwar
directed spines may have served
prop the animal up on the sea flo
with its thorax extended above it,
that its appendages could have stirr
up the mud. The broad border arou
and behind the head of *Cordania* m
have supported the animal in a simil
way. Despite this possible similar
in habit, *Cordania*, which had ey
facial sutures, and many more tho
cic segments, can be only very d
tantly related to *Cryptolithus*.

Such spinose trilobites as *Dic*
nurus, *Apianurus* (drawing, p. 1
and *Ceratocephala* can hardly ha
burrowed or dug into the sea botto
They may, however, have rested
level front and side edges of the he
on the surface of the sediment, w
thorax stretched out and limbs stirri
up the mud in search of food.

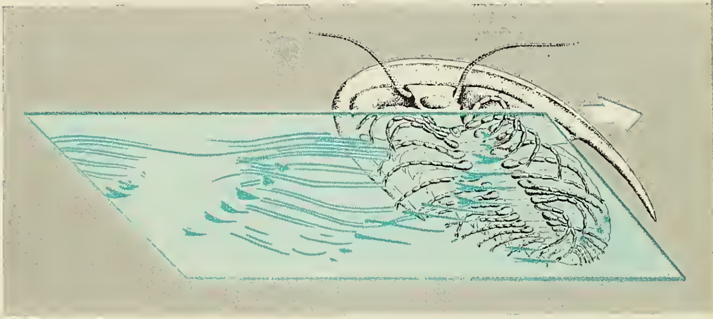
The large head plate—hypostom
of many trilobites was firmly brac
against the remainder of the he
thus affording both protection for
main organs and points of attachm
for muscles. The posterior edge of
hypostome was sharply folded, and
some species it bore spines, so t
these trilobites could have dug in
mud with their hypostomes by walk
backward. However, evidences of t
behavior, in the form of trails p
duced by such activity, have not
been recognized by paleontologis

TRILOBITES of a particular bo
form, or of an otherwise rela
group, are in most cases not fo
exclusively in any one type of s
mentary rock. Smooth-shelled fo
like *Isotelus*, for example, are foun
reef limestone, shale, siltstone,
sandstone, but so is the spiny *C*
tocephala. Some of these occurre
may result from the burial of
animal's shell in a sediment that
laid down in an environment q
different from the one in which
living animal resided. If the trilo
exoskeleton is not disarticulated
is well preserved, however, we
presume that it probably was bu
close to where it lived.

Thus, clues to the ancient envi
ment may properly be sought from
enclosing rock. Many cases in wh
this procedure has been followed
gest that particular species of t
bites possessed a wide tolerance
such environmental variables as d
of water, amount of light, temp
ture, and type of bottom sedim



Fossil tracks, called *Dimorphichnus*, *above*, probably were made by trilobite.



Tracks may have been made in manner pictured below. View is from beneath.

er species or groups of species n to have favored one environt. although they were not cond to it. The Upper Cambrian stors of *Triarthrus*, for example, abundant in dark shales, deposited agnant waters that were probably cient in oxygen. Again, *Dipleura* its close relatives are found comly. but not exclusively. in sandy ments in which they probably dug.

rilobite remains are abundant in dle Paleozoic reef rocks, and it been claimed that one smoothed form inhabited the roughr zone of a particular reef. clingto rock surfaces like a modern on. Other examples are known of ed but distinct species that are ndant in reef rocks of different and wide geographic separation.

ius there is evidence that certain bites were adapted to life in parar ecological niches in the ancient but little evidence that most were ted to a restricted environment. possession of large eyes (in *Remorides*, for example) or absence of (in *Cryptolithus*) has been held iggest a life spent in muddy or . dimly lighted waters. Analogy living arthropods. however. does point to any positive conclusions.

ie nature of the rocks that contain bite fossils suggests deposition in rs not more than a few hundred deep. Thus we have no direct evie that trilobites inhabited deep nic waters. Yet, extremely similar es (*Ptychagnostus* and *Dicranu*for example) have been shown to a world-wide distribution. Does nean that these and other kinds of ites inhabited the surface waters e oceans. feeding on the microc floating plants or animals that ituted the Paleozoic plankton? hey browse amid floating mats of eed. like those of the Sargasso to- If we assume this mode of life, iolts and dead bodies of such animight have come to rest in widely ated localities. and have been ded. in consequence, in very dift types of sediments.

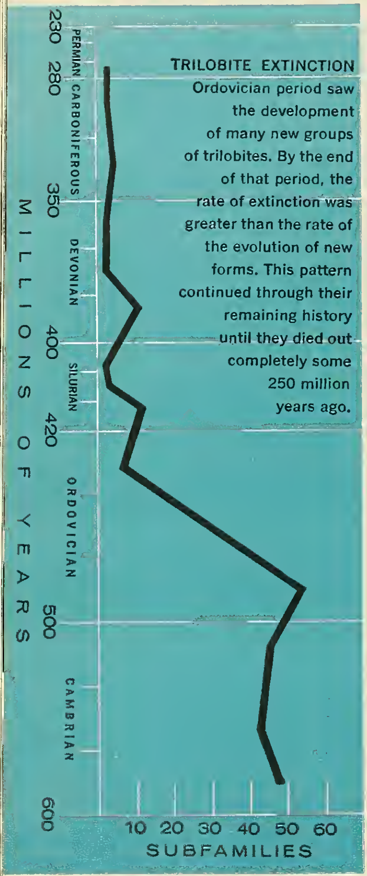
e know. however, that newly ied trilobites formed their first when they were half a millimeter in length. These tiny creatures ably floated. like the larvae of 's crustaceans. The young may existed in this stage for days or and. in that time. could have d far from the point where the eggs were laid. At a size of less than one centimeter in length in most species, trilobites became bottom dwellers in shallow water, and probably spent the remainder of their lives within a limited area. Thus, the wide geographical dispersion of particular trilobites may be explained as taking place during the larval stages, the adults dwelling on the sea bottom—not drifting in the ocean's surface water.

It has been said that spiny trilobites like *Ceratocephala* and *Apianurus* were floating forms even in the adult stage, the spines inhibiting their sinking. However. we know nothing of the appendages of these trilobites and, as mentioned, the possession of a spiny exoskeleton does not preclude the possibility of bottom-dwelling.

Some modern arthropod species exhibit sexual dimorphism—that is, male and female forms that differ in size or in other characters. More than a hundred years ago. Barrande (in that great study of trilobites from Czechoslovakia already mentioned) observed a broad and a narrow form in certain species. Today, we consider these differences to be the result of distortion that the fossils suffered when the rocks enclosing them were subjected to various stresses. Other such examples among fossils are well known. Not all the cases of two closely similar forms coming from the same rocks can be so explained, however, and it may be that sexual dimorphism did occur in trilobites. If so, however, it was not universal: the cases are equivocal.

Although during the 100 million year period of the Cambrian, trilobites were the dominant animals of the shallow seas in kinds, numbers, and sizes, they did not have these seas to themselves. There were other aquatic arthropods in existence — types that, unlike the trilobites, were armed with pincers. However, the rarity of these arthropods as fossils suggests that they were not formidable enemies of the trilobites. From the earliest Cambrian onward, a succession of new genera and families of trilobites appeared, though the rate of extinction of trilobite groups was also high.

On balance, the picture is one of great evolutionary activity, of adaptation to a great variety of environ-



TRILOBITE EXTINCTION Ordovician period saw the development of many new groups of trilobites. By the end of that period, the rate of extinction was greater than the rate of the evolution of new forms. This pattern continued through their remaining history until they died out completely some 250 million years ago.

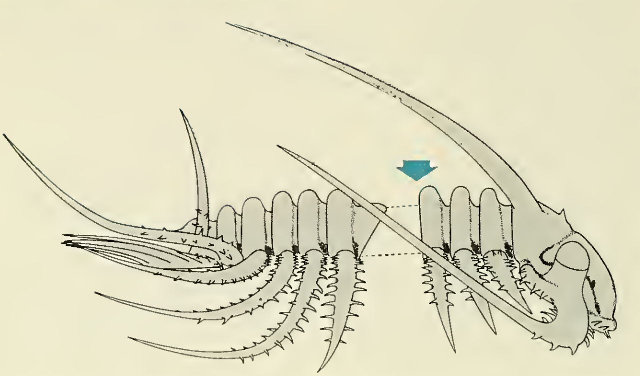
ments, expressed in a multiplicity of genera and species. At the end of the Cambrian and during the Ordovician period, this picture begins to change. New kinds of animals appeared. Previously existing ones became more numerous, and the animals must have competed with the trilobites for the food supply on and in the sea floor. Among these forms were the bivalved brachiopods and clams, and the snails. The nautiloids, molluscan ancestors of the modern *Nautilus*, were not only numerous and larger than trilobites, but probably had grasping tentacles and a powerful jaw. Such predators could have seized and eaten trilobites. But the capacity for enrollment may have afforded the trilobites some protection, and their spines must have made them an awkward mouthful. They may have lain partly buried in the bottom sediment, the projecting or stalked eyes of some species enabling them to detect nearby movement. Vegetation, clusters of marine animals such as sea lilies or corals, and crannies in reefs would also have afforded the trilobites places of concealment.

The evolution of many new kinds of trilobites in the Ordovician perhaps reflects adaptation to new environments in response to changing conditions. Yet it may be seen (diagram, *left*) that, toward the end of this period, the rate of extinction became greater than the rate of evolution of new forms. This is a pattern that continued through the animals' remaining history. Only a single group persisted through the Carboniferous and into the Permian. This decline — and th ultimate total extinction of trilobite —cannot readily be explained.

One of the mysteries of the evolu tionary process is why such fate should overtake a group of an mals that, for millions of years, wer well adapted to their surroundings an continued to evolve new species unt near the close of the Paleozoic er Phrases that imply "overspecializa tion" or "the senescence of the tril bite race" are neither apt nor mea ingful. *Ceratocephala* has been r garded as a highly "specialized" tril bite, yet its exoskeleton is known fro rocks ranging from Ordovician Devonian age—a period of some 1(million years. This is clear eviden that types of animals well adapted a particular environment may exi for an extremely long time witho significant morphological change.

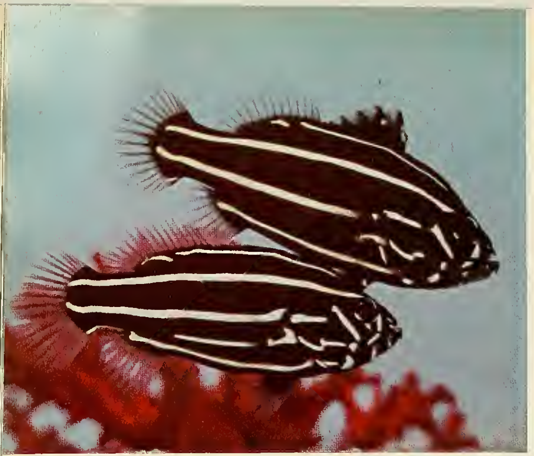
The competition for food with oth groups may have played a part in t trilobites' demise. In addition, t Devonian fishes—among which ja evolved for the first time — may ha become trilobite predators. At prese however, there is no acceptable theo that explains the reasons for extin tion of the trilobites.

New kinds of trilobites are co stantly being found on all contine (although new information on tra and on appendages collects much mo slowly). As the store of knowled from new discoveries and improv techniques of investigation accum lates, we should be able to outli more precisely the natural history these remarkable arthropods. For t present, we may agree with the l Professor Percy Raymond that p haps the greatest contribution t trilobites have made to our world ' the aesthetic pleasure the contemp tion of their elegant shells has given countless collectors and students fossils." But paleontology is a scien that does more than enjoy its r material: it also tries to bring exti animals back to life. To me, it is more exciting to try to visualize th "elegant shells" as parts of living a mals, inhabiting their particular ni in nature at a time so long ago that vertebrate animals had yet to evol.

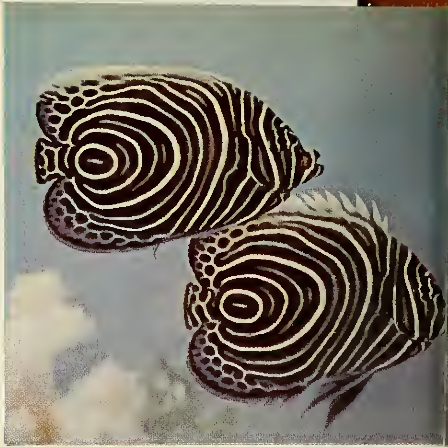


Restoration, in side view, of a spiny trilobite, *Apianurus*, demonstrates one of the problems encountered in studies of the animals. The actual number of thoracic segments is unknown, because no entire exoskeleton has been found.

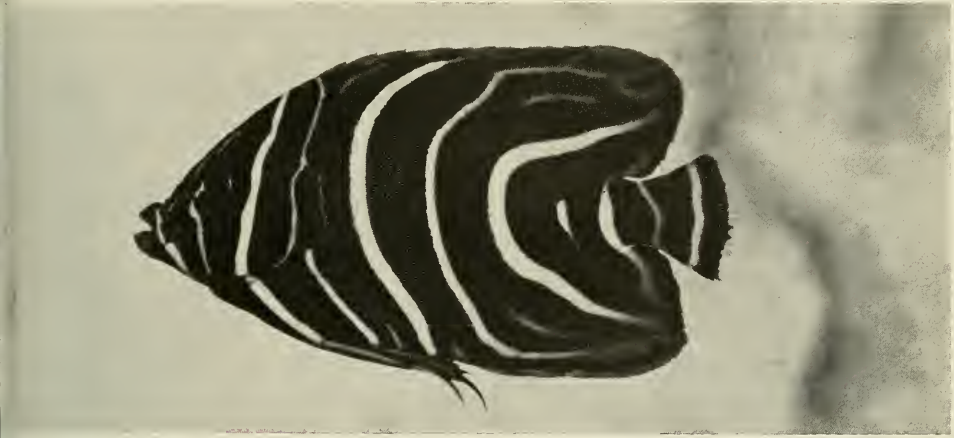
One of first trilobites ever descril from New World, *right*, was *Isote*, discovered in New York State in 1.



Golden-striped bass belongs to carnivorous marine family. As this species grows, stripes break to form short dashes.



Imperial angel fish somewhat resembles the half-circle angel when young, but changes color patterns as it mature



Half-circled angel fish, which eats animal and vegetable matter, is one of most characteristic of fishes inhabiting coral reefs. Lengths of the mature of the four different species pictured on these pages range from 10 to 16 inches.

BRILLIANT REEF FISH

Photographs by Gene Wolfsheimer

These fishes are typical inhabitants of coral reefs; as many as two hundred different kinds of them may inhabit the same reef. In no other habitat can such a variety of gorgeous creatures be seen, for although the birds and butterflies rival the fishes in number of species of resplendent beauty, few of these ever live so closely together.

The beauty of the many reef fishes is exceeded only by their diversity—in size, form, coloration, and behavior. Nevertheless, many of them are alike in the boldness of the patterns and brightness of the colors they display. This holds for one-inch gobies and six-foot parrotfishes, for the predatory, piscivorous basses and moray eels as well as small-mouthed browsers like the tangs and butterfly fishes. The existence of so many conspicuous species has raised questions in the minds of biologists, but there is only one that concerns us here. Why, in a world where the great majority of the animals try to appear as inconspicuous as possible, both to escape their enemies and deceive their prey, do most of the fishes found around coral reefs seem to outdo one another in wearing the most striking garb?

There are some instances (for example, certain scorpion fishes) in which this could be considered a case of *warning coloration* displayed by many venomous or distasteful animals, which depend on each potential enemy to make an association between their unpalatability and their particular conspicuousness. But few reef fishes are venomous.

Some ichthyologists have come to the conclusion that, whatever the function of the salient coloration of reef fishes, it is not protective at all. It may be useful in species or sex recognition but, as far as attack by fish-eating predators is concerned, only the peculiar nature of the reef makes possible the survival of such conspicuous free-swimming creatures. Coral reefs, riddled with crevices and caves, provide an agile fish with perfect terrain in which to lose a pursuer or hide from predators. Divers will vouch for this. The fishes are easy enough to see; in fact, some are insatiably curious, even to the point of tentatively nibbling at a diver's skin. But try to catch one! The speed with which it dashes to the safety of the reef, disappearing around some corner or into some hole, is incredible.

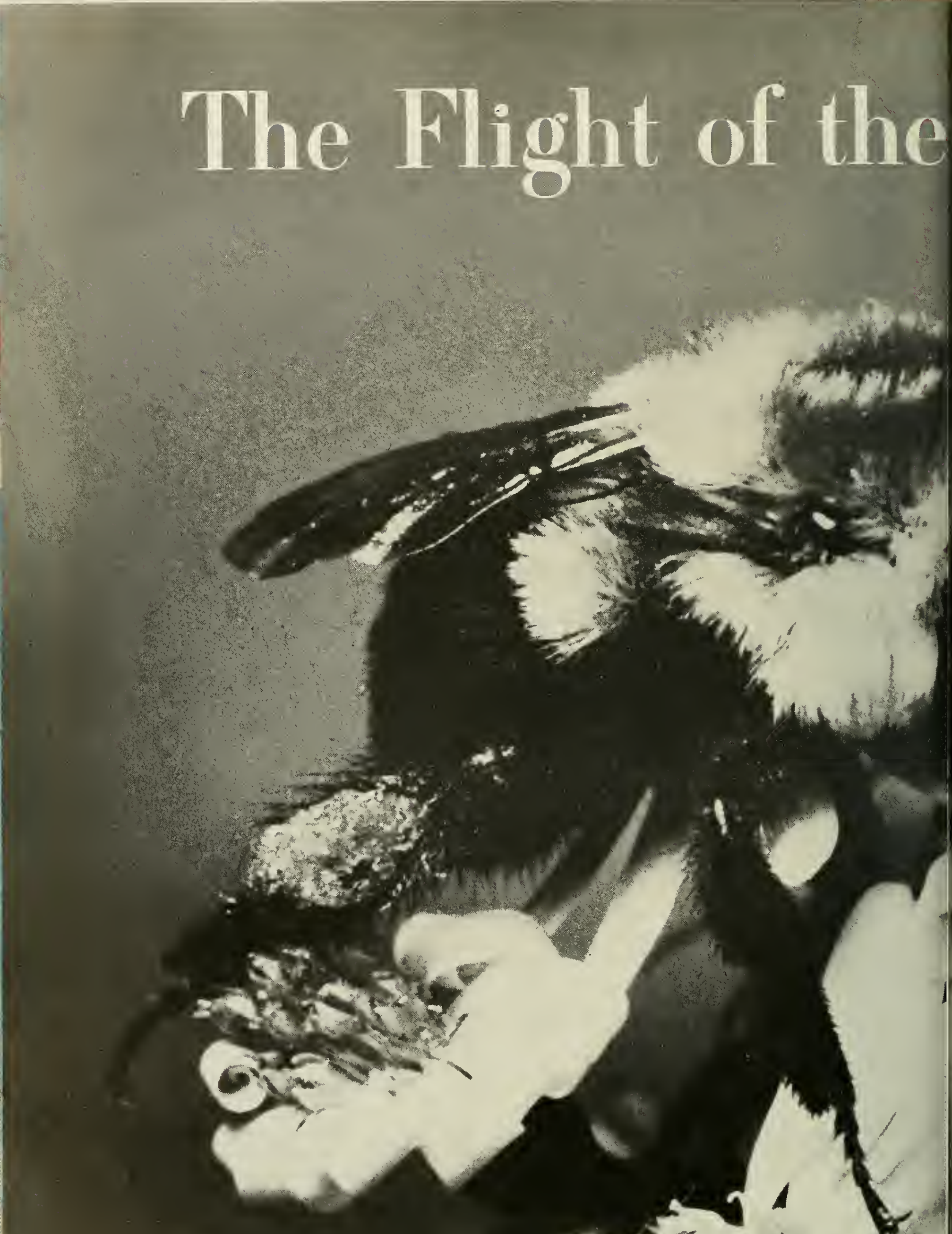
On the other hand, a number of scientists have insisted that the very conspicuousness of the colors and patterns of reef fishes helps to conceal them. These men point out that against the busy background of a reef—with its myriads of highly colored, feathery, filamentous or arborescent animals, many of them in motion—the patches of strongly contrasting colors so characteristic of reef fishes actually make a fish less visible. Catching the observer's eye, they prevent him from seeing the shape or surface of the fish itself. This *disruptive coloration*, as it is called, is dazzling. Even when photographed against a plain, artificial background, the fish requires a second, studied look to reveal all its piscine qualities. Especially noteworthy is the way in which the eye of some of these fishes is concealed by its incorporation in a dark stripe or bar.

Both of these points of view have evidence to support them, and it is probable that both hold true to some extent. Their relative importance will not be established until observers have spent many hours in underwater studies.

Sailfin tang, *left*, is member of the herbivorous family of surgeon fishes, characterized by sharp spine at the tail base.

Mr. Wolfsheimer, a California photographer, is one of America's leading raisers of hard-to-breed tropical fish.

The Flight of the



Bumblebee

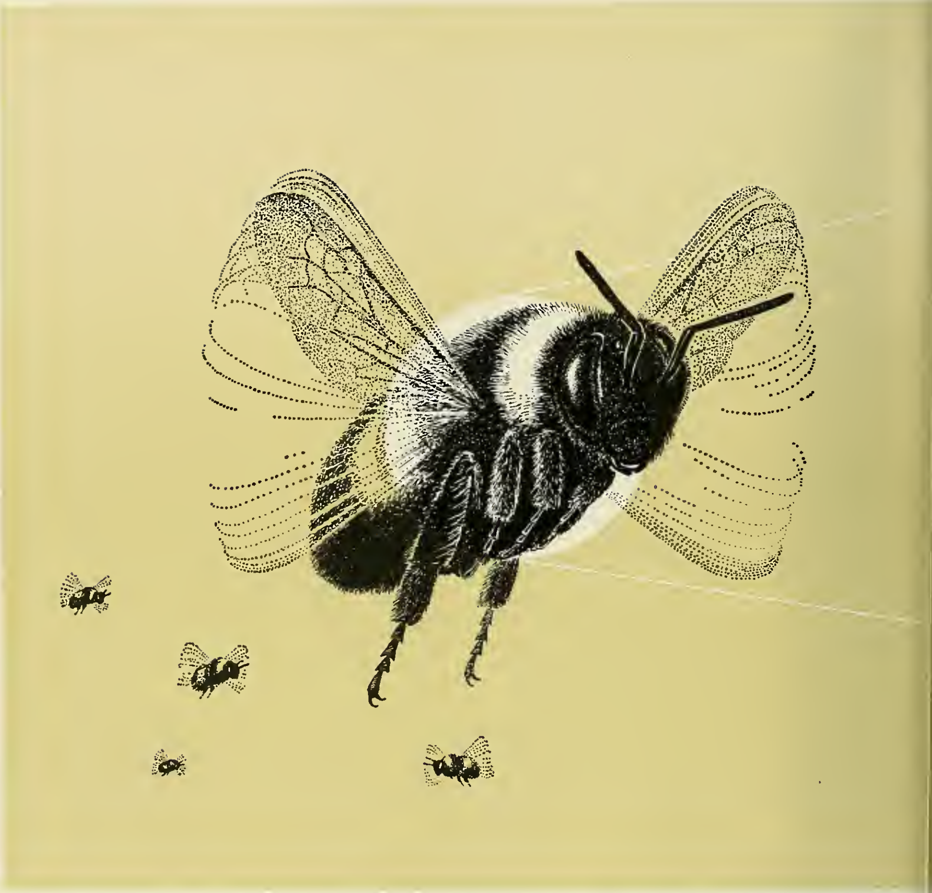
Complex anatomy is basis of control

By J. W. S. Pringle

Insects, in their mastery of flight, far surpass mankind's machines. Indeed, we know little about their flight mechanisms. Their small size and the speed at which they move their wings make even an accurate description of the wing motion difficult. The muscles that move an insect's wings have some special physiological properties, which are even less well understood than those of ordinary mammalian muscle. In the last ten years, however, considerable work has been done on insect flight by engineers, entomologists, and physiologists. This work has included studies of many different kinds of insects. For example, there are great differences between the flight of a butterfly and a gnat, yet there seems to be a sort of common plan, not only in the anatomy of wings and flight muscles, but also in the chemical reactions supplying energy for the muscles and in the nervous reflexes controlling them. An attempt will be made here to focus on the flight of the bumblebee—an insect so large and so common that anyone with a good microscope can check and extend the conclusions.

The bumblebee belongs to the order Hymenoptera, which includes the wasps, sawflies, and a large number of parasitic forms. Its flight machinery is very similar to that of the hive bee. Its two pairs of wings, like those of all insects, are very thin, elongated projections from the cuticle that covers the whole surface of the body. The joints and the sclerites, armorlike plates that cover parts of the insect's body, are hardened regions of this continuous covering. Two of these main hardenings of the meso- and metathoracic segments are the tergum, on top, and the pleura, on each side. The wings project between them.

It has been known for over a hundred years that, among the higher insects, the main power for moving the wings comes from muscles that are not attached directly to the wings, but which stretch across the thoracic cage, longitudinally and dorsoventrally (page 23). By the alternate contractions of these muscles, the thoracic "roof"—the tergum—is raised or lowered, and the wings move down and

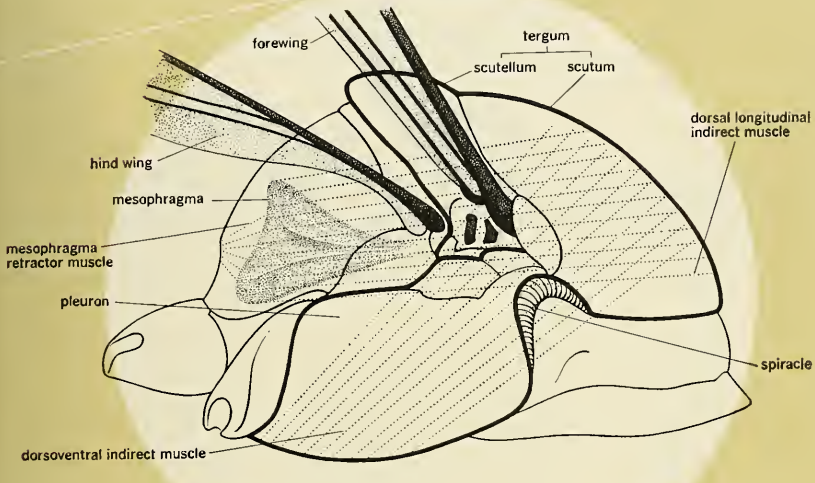


up accordingly. In the bumblebee, sclerites are arranged so that the main wing motion is diagonal—downward and forward, upward and backward. Particularly important in the bee is a subsidiary relative motion of the scutum and scutellum, two parts of the tergum. This motion serves to produce the figure-of-eight path of the wing tip and the automatic twisting of the wings that is required if aerodynamic lift is to be generated.

The hinge joint lying at the base of the bumblebee forewing is a complicated structure, composed of four small axillary sclerites. These link the three points at which the wings are attached on the thorax to the bases of the three supporting veins of the wing; the three-dimensional geometry of this region contains the clue to an understanding of the wing motion. Although it is important to realize that the whole of the wing base is really an elaborately folded surface membrane, its movements can be simplified by regarding each of these four sclerites as a separate structure articulating with the others (diagrams, page 29).

Consider the wing-stroke cycle that starts from the top of the beat, or end of the upstroke. At this moment, the large, dorsal longitudinal muscles begin to contract. These are attached behind a large sclerite, the mesophragma, which in the intact bee is entirely hidden underneath the metathorax and first abdominal segm t. Taking one side only, the front en of the mesophragma pushes on the u- tellum: this connects with the l g. lower arm of the first axillary l h directly and through the head of he axillary lever and the fourth axil ry (page 29, *top*). The middle of the st axillary connects to the scutum: he result of the push from the m o- phragma is to rotate the first axil ry forward and downward. The u er "crook" of the first axillary, in t n, connects with the leading edge of he forewing, and the wing is twiste so that its leading edge is depressed.

This twisting movement is lin ed because the scutellum hits agains he scutum. When this happens, the n-


forewing
tergum
scutellum
scutum
dorsal longitudinal indirect muscle
hind wing
mesophragma
mesophragma retractor muscle
pleuron
spiracle
dorsoventral indirect muscle

MESOTHORAX, in black outline, is enlarged middle segment of queen's thorax. Dorsoventral indirect muscles stretch across segment; dorsal longitudinal indirect muscles reach to mesophragma. Forewings join between tergum and pleuron.

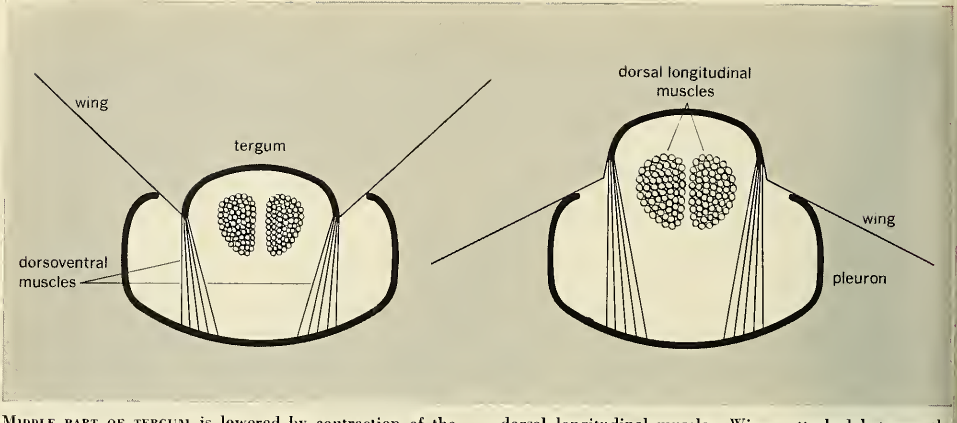
tinued contraction of the muscle lifts both sides of the thoracic roof—composed, as we have seen, of scutum and scutellum together—in relation to the side plates, or pleura, and the downstroke of the whole wing begins. Because this downstroke is preceded by the wing-twisting, the wing moves down in a pronated attitude, rather as if the lower arm and hand in a human were rotated in such a way that the palm turned downward.

Contrary to the description given in most textbooks, the wing's upstroke is *not* just a reversal of this sequence of events. Actually, the path of the wing tip on the upstroke is different from that on the downstroke, and the wing is twisted in a different way. At the beginning of the upstroke, it is the dorsoventral muscles that start to contract, lowering the thoracic roof on the pleura. The wing is connected to the roof through the first axillary, as has been noted. But it is also connected to the pleuron through the second axillary, and these two axillaries also articulate with each other. The initial effect of lowering the roof is to rotate both axillaries *backward* and downward, twisting the forewing in opposite fashion. As at the beginning of the upstroke, this initial twisting movement is limited by a stop. The stop is formed, in this case, by the backwardly directed arm of the second axillary, which fits into a socket located on the pleuron.

As the dorsoventral muscles continue to contract, further depression of the roof raises the wing, but it now pivots about a different axis; the wing tip performs its upstroke more horizontally, and is raised only later. The relative movement of scutum and scutellum has been reversed in this process and, as the wing reaches the top of its stroke, the whole cycle is repeated.

To summarize, the whole stroke cycle of the forewing can conveniently be considered in four phases:

(1) Movement between scutum and scutellum, rotating the first axillary forward and downward and the second axillary forward and upward. This pronates the wing and sets the axis of the downstroke movement more



Middle part of tergum is lowered by contraction of the dorsoventral muscles and raised by a similar action of the dorsal longitudinal muscles. Wings, attached between the tergum and pleuron, are raised and depressed by movements.

nearly horizontal, so that the wing tip moves downward more nearly vertically. This phase is limited by the scutum-scutellum stop. It is followed by:

(2) The downstroke.

(3) Initial lowering of the thoracic roof (tergum), rotating the first axillary backward and second axillary backward and downward. This supinates the wing and sets the axis of the upstroke more nearly vertical, so that the wing tip moves upward more nearly horizontally. This phase is limited by the stop between the backwardly directed arm of the second axillary and the pleural socket. The cycle is followed and completed by:

(4) The upstroke.

Having analyzed the mechanics of the wing-stroke cycle, we must now consider the muscles involved in flight. In all insects there are, in addition to the large, *indirect* muscles stretching right across the thorax, many other muscles that affect the wing motion. Some of these pull directly on the wing base or on the axillary sclerites; some insert on the tergum or pleuron near the wing base; some alter the elasticity of the whole thoracic box by pulling between its component parts. In primitive insects, and in some of the higher groups, especially dragonflies and beetles, some of these direct muscles are large and contribute part of the power for the wing strokes. But in bees, and nearly all Hymenoptera, all the power for the stroke comes from the indirect muscles; the other muscles are small, being merely adjusters that are used in the control of flight.

It is obvious that a bumblebee does not only fly forward at a steady rate; it can maneuver in the air with considerable skill. It has no auxiliary control surfaces, such as the individual feathers in the tails of birds, to enable it to do this; its maneuvers have to be produced by alteration in the form of the wing motion as a whole. There have been various attempts to understand how the many small muscles function to produce these modifications of wing motion, but many of them have failed to take into account one fundamental feature of the bee's flight system. In nearly all animals, muscles contract with the arrival of impulses through nerves connecting them to the central nervous system (brain or ganglia). When such a nerve impulse arrives, the muscle performs a twitch involving a brief contraction and relaxation. If nerve impulses arrive at a sufficiently high rate, most muscles do not have time to go through their contracting and relaxing cycle and, as a result, go into a steady contraction, or tetanus.

Mammalian muscles, for example, cannot perform separate twitches at a rate much above twenty per second. The flight muscles of grasshoppers and moths are faster, and can give separate twitches up to frequencies as high as ninety per second.

Apparently, no such muscles have evolved that are sufficiently fast to twitch more rapidly than about 100 times per second. Those insects whose wingbeat frequencies are higher than this (and in some flies the frequency is as high as 1,000 beats per second) have evolved a different method: the muscles that move their wings do not perform a single twitch on the arrival of each nerve impulse. Instead, they generate an oscillatory contraction, the frequency of which is determined by the mechanical properties of the muscle itself and by the load it is moving. This mechanism of rhythmic contraction is not limited in its speed o action, and insects possessing this sor of flight muscle can therefore mov their wings at a much higher rate. Furthermore, it becomes unnecessary fo the nerve impulses to be related t each cycle of the rhythm. In fact, in bumblebee, with a frequency of 15 to 200 beats per second, the impulse to the flight muscles are quite slow— only about 10 impulses per second— even when the muscles are contractin rhythmically 200 times per second.

The muscles that function in thi rhythmic manner are different i appearance from ordinary muscles They are usually redder, owing to th concentration of pigments involved i the high rate of chemical energy supply needed for their intense activit They are composed of somewha thicker fibers. Once these facts are recognized, it becomes a simple task t determine which of the flight muscle of any particular insect are contrac ing at the frequency of the wingbeat and are producing power for th strokes, and which muscles are merel controlling the form of the wing motion by an adjustable, steady pull on the various moving parts of the thorax and the wing articulations.

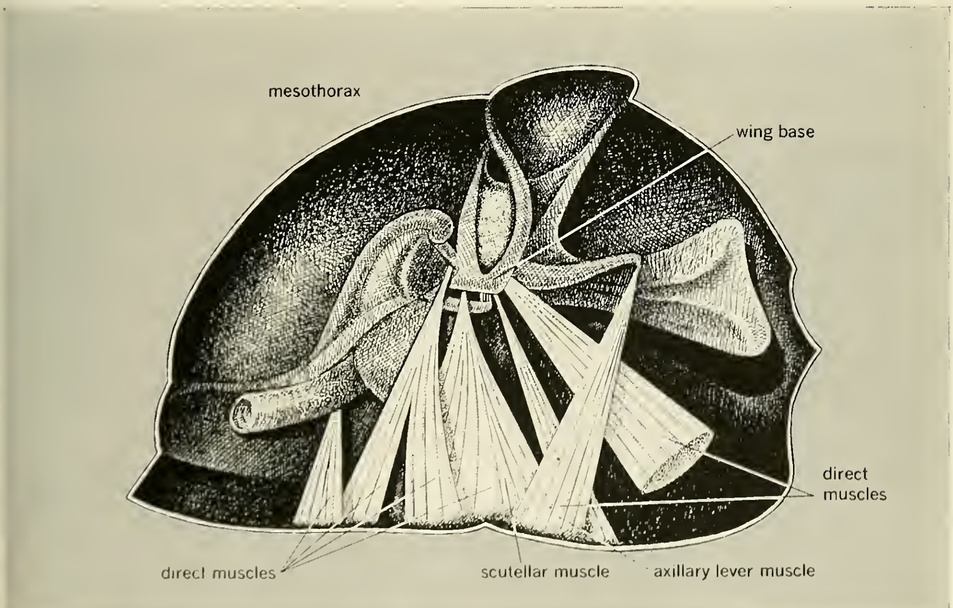
In the bumblebee, only the large, indirect dorsal longitudinal and dorsoventral muscles of the mesothorax have this particular structure and rhythmic function. All the muscles of the metathorax (the segment bearing the bumblebee's hind wings) and all smaller muscles of *both* segments are normal in appearance, and cannot contract during flight at the frequency of wing motion. The fact that these latter muscles must modify flight by a *steady* pull on the moving parts gives the essential clue to an understanding of their mode of operation.

What sort of changes in the wing motion are required to give control of movement through the air? Many of us are familiar with the control system used in a conventional aircraft. The three planes of space in which control is required are known as the pitching (fore-and-aft), rolling (banking sideways), and yawing (turning about a vertical axis) planes. In aircraft, the three forms of control are provided, respectively, by the elevator, ailerons, and rudder. An insect, however, has no auxiliary control surfaces, and in this respect is more similar to a helicopter. In a helicopter, control in pitch and in roll can be obtained either by tilting the whole plane of the rotor, or by arranging a system of cams so that the twist (incidence) of the blades is altered in different parts of the circle of rotation. Yaw control is usually obtained from an auxiliary propeller, as the main rotor turns in a horizontal plane.

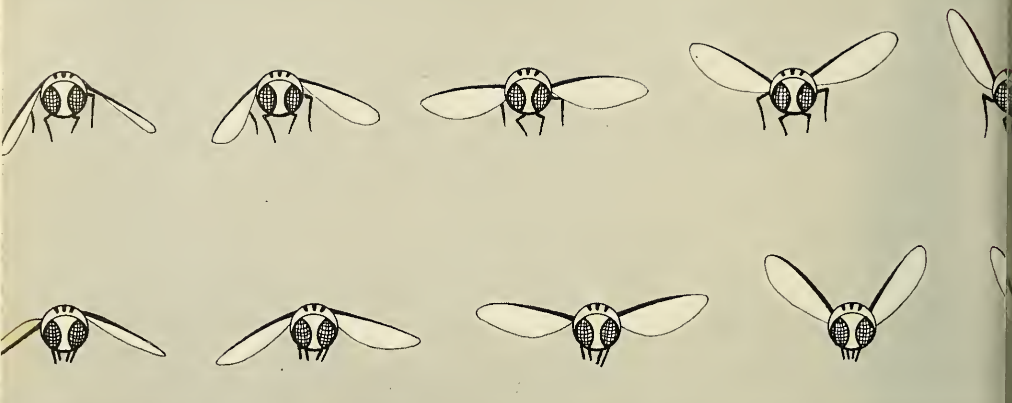
INSECTS do not have rotating wings. The paths of the two wing tips, however, do not lie wholly in one plane, and it is this that makes auxiliary control surfaces unnecessary. In the bee, as in other insects, control in all three planes of space is obtained by the methods used in a helicopter in controlling the pitch and roll—alteration of the plane of wing vibration and differential twisting in different parts of the stroke. The articulations at the base of the insect's wings are of such perfect design that all these types of control can be obtained by the steady pull of small muscles on a number of different moving parts.

Unfortunately, we as yet have no high-speed pictures of a flying bee that could give evidence of the actual control movements used by this insect. But Dr. Richard Faust, Director of the Zoological Gardens at Frankfurt-am-Main, made some photographic studies of the bluebottle some years ago, and it is reasonable to assume that the results he obtained are also applicable to other fast-flapping insects. Dr. Faust obtained his photographs by fixing a fly by the top of the thorax so that it could still move its wings, and mounting it on the axis of a rotating shaft in various orientations. When the shaft turned, the fly tried to compensate for the rotation by altering its wing-twisting.

The first thing that became clear was that control movements occur during the downstroke; the upstroke never changed. During rolling movements, one wing was more twisted than the other in the *later* part of the downstroke; this is the phase during which the horizontal movement of the wing is greatest, and in which, therefore, the two wings generate different lift, and roll the fly back into a level attitude. In the yawing movements,



INSIDE THE MESOTHORAX near wing base are direct muscles, including scutellar muscle, whose pull opposes wing twist in basic stroke cycle and probably controls pitching, and muscle of the axillary lever, which controls flight power.

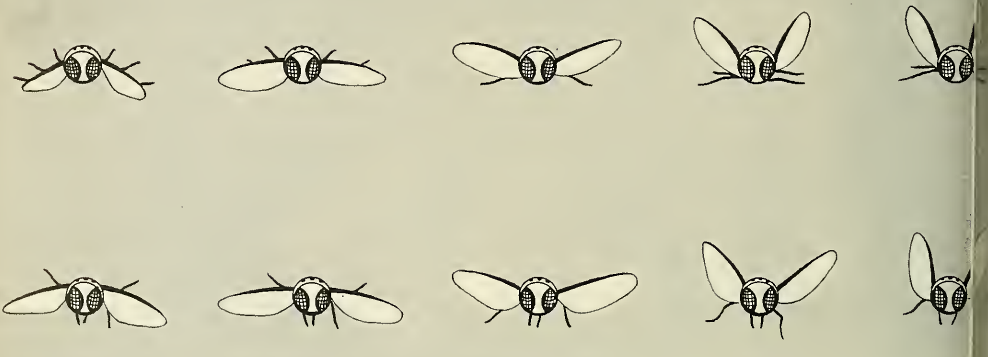


Control of flight motion is accomplished by alternating plane of wing vibration at different parts of the downstroke, as upstroke does not change. Paths of two wing tips are no wholly in one plane, so no auxiliary control surfaces are

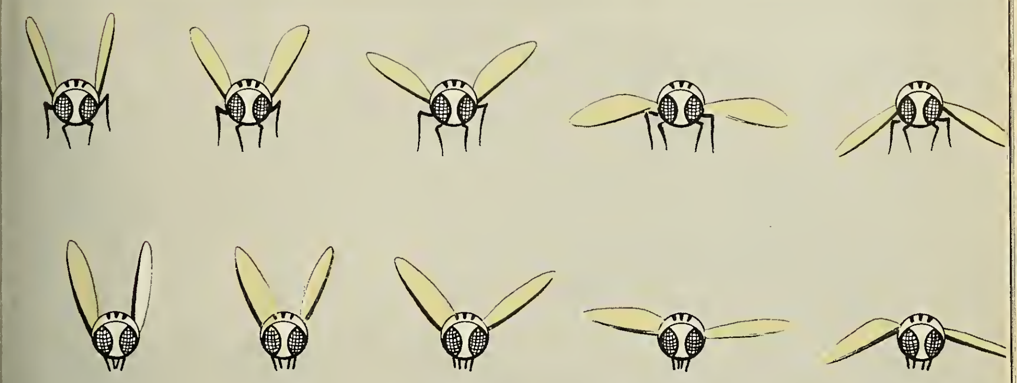
the wings were differently twisted during the *middle* part of the downstroke; in this phase, the vertical wing motion was greatest, and the result of the different incidence on the two sides produced a compensatory yawing torque. During forward pitching movements, the wings on both sides had an equal and large supination twist at the start of the downstroke, when they were farthest up, and at the end of the downstroke when they were farthest forward. Thus, they acted together to resist forward pitching (drawings, *above* and *below*).

These experiments show how it is possible for a bluebottle with one pair of wings to control its attitude despite the lack of auxiliary surfaces. The bee has a second pair of wings but these are tightly coupled to th forewings by hooks, and act as a single airfoil surface. Probably the hin wing muscles can alter the effectiv wing section of the whole surface b bending the back part up or down i relation to the front part.

The bee seems also to have developed a more efficient mechanism tha



Yaw to right, in which insect is turned on vertical axis, is diagramed in upper strip. In this balancing, each wing is twisted differently during middle part of the downstrok and result of different incidence produces a yawing torqu

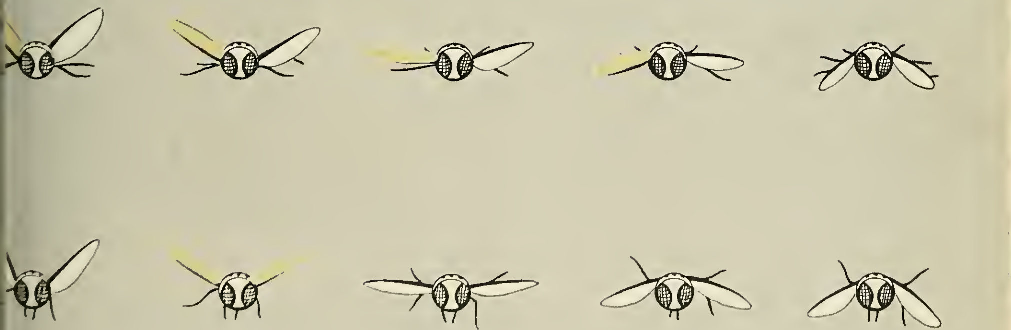


ecessary. Diagrams across top show wing positions during ormal flight, next strip demonstrates action in resisting a roll to left. In latter case, notice that one wing is more twisted than the other during later part of the downstroke.

he fly for altering the entire stroke lane, so that the wings can beat more orizontally or more vertically. Thus ot only has it both kinds of the con-rols used in helicopters, but may also ave another in the control of the ing section. No wonder its powers of aneuver are so efficient!

It is not easy to be sure exactly how ll the small control muscles of the bee work, but careful dissection, coupled with a knowledge of the type of wing-twisting required, makes it possible to put forward some suggestions. Some of these are reasonably well established; others await confirmation by subsequent researches.

The mechanism of wing-folding is clearly understood. In both pairs of wings it is brought about by muscles attached to the knob halfway up the third axillary sclerite. When these muscles contract, the third axillary turns about its axis and pivots about its base, carrying the hind part of the wing upward and backward. The wing turns about the second axillary, and the base of the leading edge disengages from the upper arm of the first axillary. This is the typical method of



t bottom is wing action during the fore-and-aft pitching otion. Here the wings have large, equal twist at start of the downstroke, when they are farthest up, and at end of the same stroke when farthest down, to resist forward tumbling.

Dr. Pringle, Fellow of the Royal Society, specializes in experimental cytology at Cambridge University, where he has been a Fellow and the Librarian of Peterhouse since 1959.

wing-folding found in all insects that perform this movement.

Unfolding at the start of flight is not performed primarily by muscles attached directly to the wings. It results from the simultaneous tonic contraction of both dorsal longitudinal and dorsoventral indirect muscles, which strain the whole thorax so the wings unfold. Tests on a freshly killed bee show that for the unfolding movement to occur properly it is also necessary for the dorsal longitudinal muscle of the metathorax (the retractor of the mesophragma) to be tonically contracted, so that the mesophragma is not allowed to move forward. It is interesting to remember that, in evolution, this muscle must have been responsible for the downstroke of the hind wing. The nervous mechanism originally responsible for keeping this muscle active during flight still operates, but its steady pull during flight now serves to keep the wings unfolded, and to transmit passively to the hind wing some of the power that is produced in the dorsal longitudinal muscle of the mesothorax.

The path of the wing tip can certainly change during control movements, so that the whole cycle of movement takes place with the wing pulled more or less forward, and in such a way that the figure-of-eight path alters in shape. The forward positioning of the wings is probably produced by the basalar muscle, which pulls through a ligament on the leading edge. The alteration of the shape of the figure-of-eight is a more complicated process, involving a relative change in the magnitude of phase one of the basic wing-stroke cycle in relation to phase two. Phase one, involving the forward movement of the scutellum against the scutum and a rotation of the first axillary sclerite to produce pronation, is normally terminated by the operation of the scutum-scutellum stop. A muscle attaches to the scutellum in such a way that its contraction will tend to resist the movements of phase one and allow phase two to start earlier. This must have two effects: the wing is carried forward rather than downward in the early part of the downstroke, and it moves forward with a high angle of incidence, because of its lack of pronation. This is exactly the form of wing motion Faust found compensating for forward pitching rotations in the bluebottle, and it is reasonable to conclude that scutellar muscles are mainly used by the bee for pitch control.

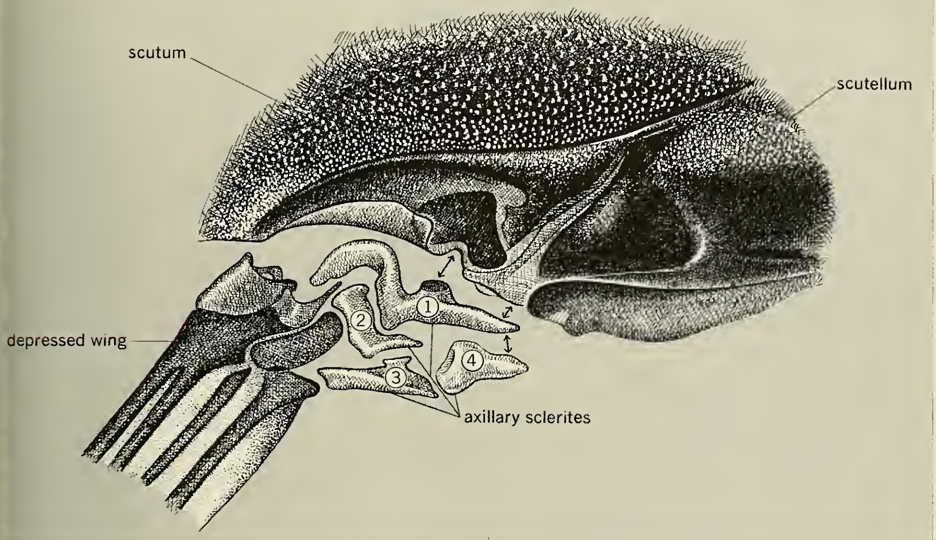
Faust did not study the changes in the path of the wing tip during compensatory control reactions, but there is some evidence on the point from some experiments on the stable fly by F. S. J. Hollick in 1940. He found that a fly in still air moved its wings downward at the beginning of the downstroke and had a tendency to pitch forward. In a current of air, the wing tip path at the beginning of the downstroke was forward and the pitching tendency disappeared. Probably this compensation was being controlled by a muscle analogous to the bee's scutellar muscle for pitch control.

Control of yawing movements in the bee is probably done by the subalar muscle of the forewing, which pulls through the subalar sclerite on the lower arm of the second axillary and on the base of the third axillary. This action should tend to increase the wing's drag during the downstroke, especially during the middle part, when vertical velocity is greatest.

Control of rolling movements in the bee, unlike that of the fly (which has only one pair of wings), is probably done by the muscles of the hind wing. We have already noted that the airfoil surface in the bee comprises the two wings, tightly coupled together, the power for the stroke being delivered entirely into the forewings. The muscles of the hind wing, comparable in size and structure to the other slowly contracting muscles involved in the control of flight, must be mainly responsible for the changes in wing section by altering the relative attitudes of the fore- and hind wings. During the downstroke, the whole surface will be more convex if the hind wing is relatively depressed, and this shape will contribute more lift during the later part of the downstroke. A different camber on the two sides of the body will generate a rolling torque. The muscles involved on each side are the subalars of the hind wing and the indirect dorsoventrals of the hind wing, pulling the wing down or up, respectively. Both are well developed in the metathorax and function antagonistically, thus delicately controlling this important feature of the mechanism.

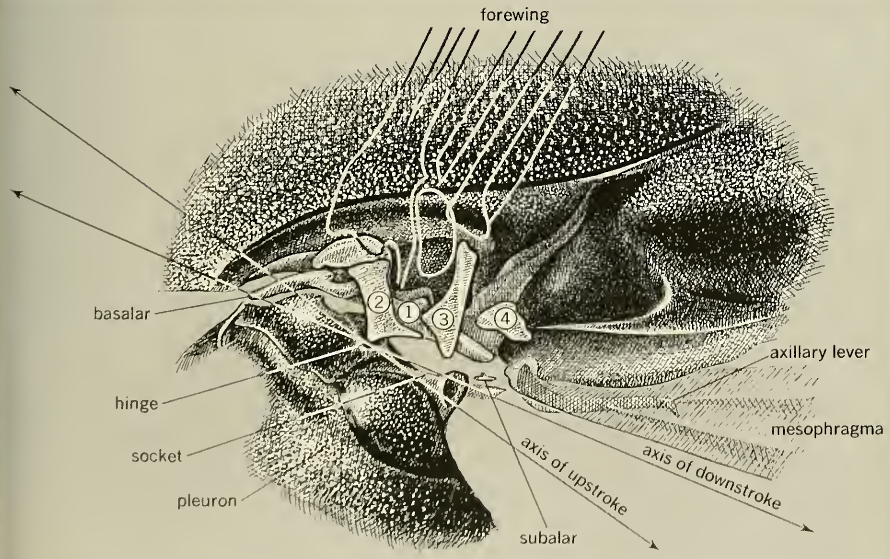
The most remarkable special feature of the wing articulation of bees is the structure known as the axillary lever. It is clear that the function of this structure is to control the power of flight and the amplitude of wing movements, with some control of the stroke plane (the angle to the horizontal of the average path of the wing tip). The German entomologist Stellwaag noticed in 1916 that bees seem to make more use than do other insects of changes in the stroke plane, and we now know that this is an incidental feature to changes in the amplitude of beat. The axillary lever is, indeed, a lever in the true sense. It pivots about the front end of the mesophragma, and has a short arm with a socket in which rests a pointed projection from the pleuron and a long arm, directed backwards, that bears a downward-pulling muscle at its end. When this muscle contracts, its force is enormously magnified by the lever action; a rather small tonic muscle can thus displace the mesophragma backwards and move the main wing articulations relative to each other, in spite of the fact that the whole power of the large indirect muscles is being transmitted through these structures. Like all muscles, the indirect wing muscles deliver more power when they are stretched, and the amplitude of the wingbeats is therefore increased. At the same time, the axis about which the downstroke (phase 2) occurs is tilted, and the stroke plane becomes more nearly vertical. This must have the effect of increasing the forward component (thrust) of the downstroke's aerodynamic force in relation to the upward component (lift). The action is like that of an accelerator; instead of just hovering, the bumblebee is able to move forward through the air.

One of the most interesting aspects in a study of insect flight is the continual discovery of new ways in which the aircraft designer has unknowingly copied these accomplished fliers. Some years ago, instrument engineers produced an aircraft blind-flying device that works on the same principle as the fly's gyroscopic sense organs, known as the halteres (Natural History, February, 1948). Now there is a helicopter in which contro of forward motion is achieved by wha is, in essence, the bee's axillary lever


scutum
scutellum
depressed wing
1
2
3
4
axillary sclerites

EPRESSED FOREWING, with axillary sclerites at base, is sarticulated, *above*. (1) and (2) slide over each other, ıd (4) is tied to (1) and (3). Arrows indicate the points which sclerites articulate to suspend wing from thorax.

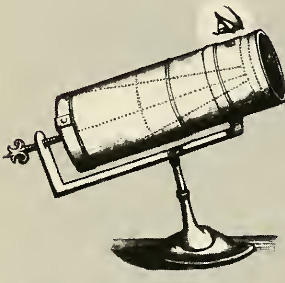
NATURAL POSITION of sclerites is seen from beneath wing, *below*. Mesophragma's push at start of downstroke rotates first axillary, pronating wing. On upstroke, the rear arm of second fits into pleural socket, changing axis of movement.


forewing
basalar
2
1
3
4
axillary lever
hinge
mesophragma
socket
pleuron
axis of upstroke
axis of downstroke
subalar

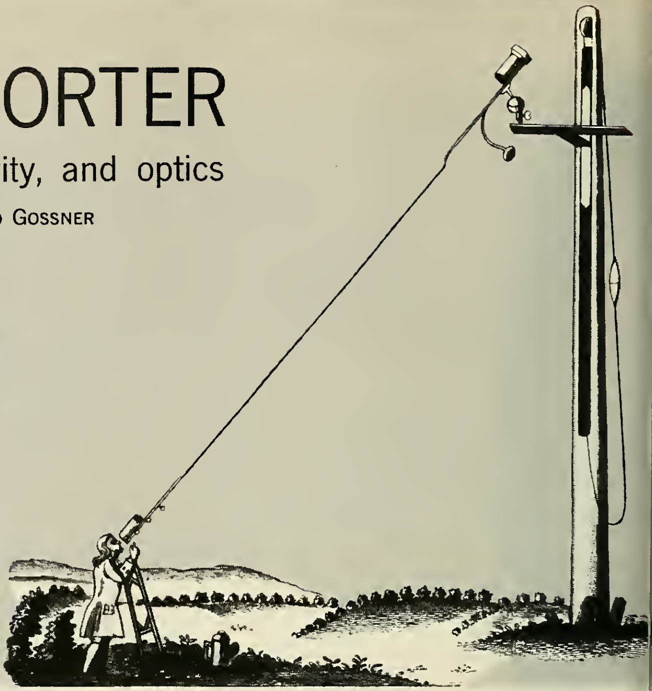
SKY REPORTER

Isaac Newton, gravity, and optics

By Simone Daro Gossner



Reflector telescope, invented by Isaac Newton, was only six and one-half inches long. The image was viewed from side (inset eye).



Aristotle had taught that a body is kept in motion by the constant application of a force and that it comes to rest when the force subsides. Galileo's studies of the motions of falling bodies constitute the first challenge to this erroneous concept; although he did not express it in these terms, his results imply that, if a body is not subject to the action of any force, it is either at rest or traveling at constant speed along a straight line; whereas an applied force would deflect, accelerate, or retard its motion (these conclusions were eventually formulated by Isaac Newton).

Concern for the cause of celestial motions was also evident in Kepler's work. In *Harmonice mundi*, he intimated that planets are kept in orbit around the sun by some power emanating from that body. This was, however, a purely philosophical concept, without bearing on his empirical determination of the shapes of orbits. Nevertheless, the question was definitely in the air from the beginning of the seventeenth century. If its solution eluded Kepler, this was partly because the Lutheran mystic did not have at hand the necessary mathematical tools.

Isaac Newton (born in 1643, the year after the death of Galileo) devised a primitive form of calculus that became the key to his success. Driven to the country by an outbreak of the plague in London, in 1665, he devoted his enforced leisure time to a study of the motion of the moon. His approach was prompted by an analogy with the fall of objects on earth: anything dropped falls vertically to the ground, but an object tossed laterally (such as a ball in play) describes an arc before reaching the ground; and the stronger the toss, the longer the arc.

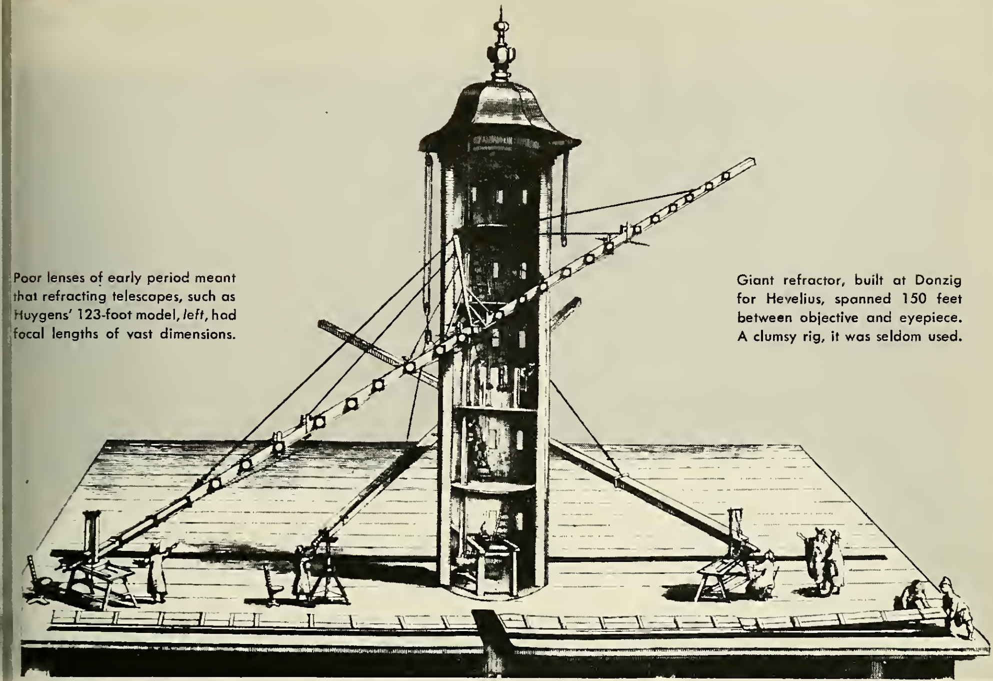
Conceivably, if the object could be imparted enough speed, its trajectory could be lengthened to the point where it would no longer return to earth, but would remain in orbit around it. Before he could apply this concept to t case of the moon, the young Newton was faced by anoth problem. If, indeed, an object falls to earth because of t latter's gravitational pull, how much remains of this p at the distance of the moon (in other words, how mu attraction has to be counteracted by the moon's lateral— orbital—speed)? At this point Newton had to make educated guess, and the measure of his genius lies in t fact that he guessed right.

Having assumed that planets are kept in orbit arou the sun by a similar gravitational pull from that body, noted the remarkable relation expressed in Kepler's thi law of planetary motion (*Sky Reporter*, May, 1961), nan ly, that the square of a planet's period increases as the cu of its mean distance from the sun. This means, of cour that—the farther it is from the sun—the less is the orbi speed of a planet: a first indication that the effect of gra tation lessens with increasing distance. This also mea that this reduction of gravitational pull does *not* occur direct proportion to the distance itself. Newton guess that its effect varies inversely as the *square* of the distan and set about to verify his hunch.

Returning to the earth-moon system as a model, Newt used his newly invented calculus (which he called "meth of fluxions") to compute what orbital speed the mo should have to counteract the earth's attraction. His res differed by about 10 per cent from the observed value. cause of this discrepancy and because of a mathemati difficulty, which he had not resolved to his satisfacti Newton did not publish his theory at that time.

A few years later, a group of French scientists set out redetermine the length of the earth's radius. They fou that earlier estimates had been in error by about one-si

Poor lenses of early period meant that refracting telescopes, such as Huygens' 123-foot model, *left*, had focal lengths of vast dimensions.



Giant refractor, built at Danzig for Hevelius, spanned 150 feet between objective and eyepiece. A clumsy rig, it was seldom used.

f the adopted value. Since the moon's distance is known rimarily as a function of the terrestrial radius, here lay e source of the discrepancy in Newton's results. When e returned to his problem, Newton soon arrived at a com- ete verification of his theory. As further convincing roof, he was able to show that Kepler's laws may be de- ved mathematically from his own law of gravitation.

No less important to the progress of cosmological ideas were Newton's discoveries in the field of optics. Ob- rving, as Grimaldi had done before him, that a glass ism disperses a ray of white sunlight into all the colors the rainbow, Newton proved experimentally that these lors are elementary components of white light, and he cribed their dispersion to the fact that each color is fracted differently. His conclusions were the first step ward the development of astronomical spectroscopy, a easurement technique by means of which it has become ssible to study the composition and temperatures of stars.

Until Newton's time, the only telescopes in existence ere refractors; that is, combinations of lenses. Their ajor drawback was a defect called chromatic aberration, used by the fact that the edges of the lenses act as so any prisms, and the resulting images appear surrounded a rainbow-hued halo. In modern instruments, this defect removed by combining lenses with different refractive operties that compensate each other. In the seventeenth ntury, however, the only way astronomers knew of mini- izing chromatic aberration was to increase the focal ngth of their telescopes. At the same time, they craved ider lenses in order to observe fainter stars. But, for ery inch added to the diameter of the lens, the focal ngth grew by several feet. As a consequence, refractors of that epoch became so long and unwieldly that it was no longer possible to encase them in solid mountings. Typical of these monstrous rigs were the instruments erected by Christian Huygens (above, at center) and Johannes Hevelius (above) in which objective and eyepiece were aligned by a simple rod or a length of string.

Newton mistakenly believed that there was no other way of correcting refractors for chromatic aberration. In order to construct telescopes of more suitable size, he saw no alternative but to replace lenses by mirrors, which merely reflect light without color dispersion. Although the idea of substituting mirrors had been advanced by others, he was the first to design and build a workable model.

Ordinary glass mirrors were unsuitable because their reflective coating is applied to the *back* of the glass, which the light must still penetrate (and thus be refracted) before it is reflected (the process, used in modern telescopes, of depositing a film of silver on the front of the glass is a nineteenth-century invention). The only other possibility was to use a metal mirror, and Newton's success derived from his selection of a suitable alloy, the so-called "bell metal" containing six parts of copper and two parts of tin, to which he added one part of arsenic.

His first telescope (above, at left) was only six and one-half inches long. The principal mirror, at the bottom of the tube, was shaped to a spherical surface, and the reflected light rays were further deflected to the side of the tube by a small, secondary mirror. The performance of Newton's instrument was far inferior to that of its contemporary refractors, but its principle aroused considerable interest among scientists. In the centuries that followed Newton, large reflecting telescopes were to become the foremost instruments for the astronomical exploration of the universe.

THE SKY IN AUGUST AND SEPTEMBER

From the Almanac:

Last Quarter	August 3,	6:48 A.M., EST
New Moon	August 11,	5:36 A.M., EST
First Quarter	August 19,	5:52 A.M., EST
Full Moon	August 25,	10:14 P.M., EST
Last Quarter	September 1,	6:06 P.M., EST
New Moon	September 9,	9:50 P.M., EST
First Quarter	September 17,	3:24 P.M., EST
Full Moon	September 24,	6:34 A.M., EST

The sun will cross the celestial equator from north to south on September 23 at 1:43 A.M., EST (equinox). Autumn will begin on that date in the Northern Hemisphere.

For the visual observer:

Mercury, in the morning sky at the beginning of August, will be in superior conjunction on August 14 and will enter the evening sky on that date. It will remain an evening star throughout September and will set about an hour after the sun all month long. Poorly placed for observation in August and most of September, it will become more favorable for a few days about September 28. the date at which the planet reaches its greatest eastern elongation.

Venus will rise at 1:45 A.M., local standard time, on August 1, at 2 A.M. on August 15, at 2:30 A.M. on September 1, at 3:00 A.M. on September 15, and at 3:30 A.M. on September 30. It will be conspicuous in the eastern sky at sunrise. Venus will pass south of Castor and Pollux in the constellation Gemini at the end of August.

Mars (+1.9 magnitude) will move from Leo to Virgo in August and will remain in Virgo throughout September, passing north of Spica about September 20. An evening star, it will set soon after the sun during these months and will be difficult to see, very low in the western sky.

Jupiter (—2.2 magnitude) will be found in Capricornus in August and will move to Sagittarius in September. In the evening sky, it will cross the meridian at about 11:30 P.M. on August 1, at 10:30 P.M. on August 15, at 9:30 P.M. on September 1, at 8:20 P.M. on September 15, and at 7:20 P.M. on the final night of that month.

Saturn, in Sagittarius (+0.6 magnitude), will be approximately five to six degrees west of Jupiter in August and September. Therefore it will cross the meridian each day about twenty to twenty-five minutes before Jupiter.

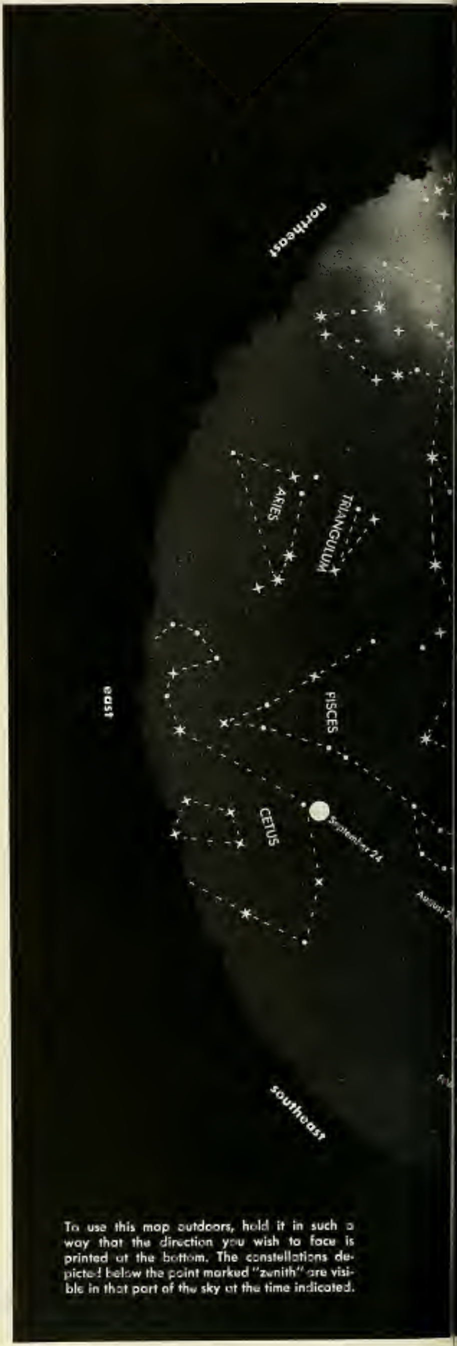
The Perseid meteor shower will reach its maximum intensity on August 12, one day after New Moon. Barring inclement weather, as many as fifty meteors per hour may be seen by an alert observer away from city lights.

Eclipses:

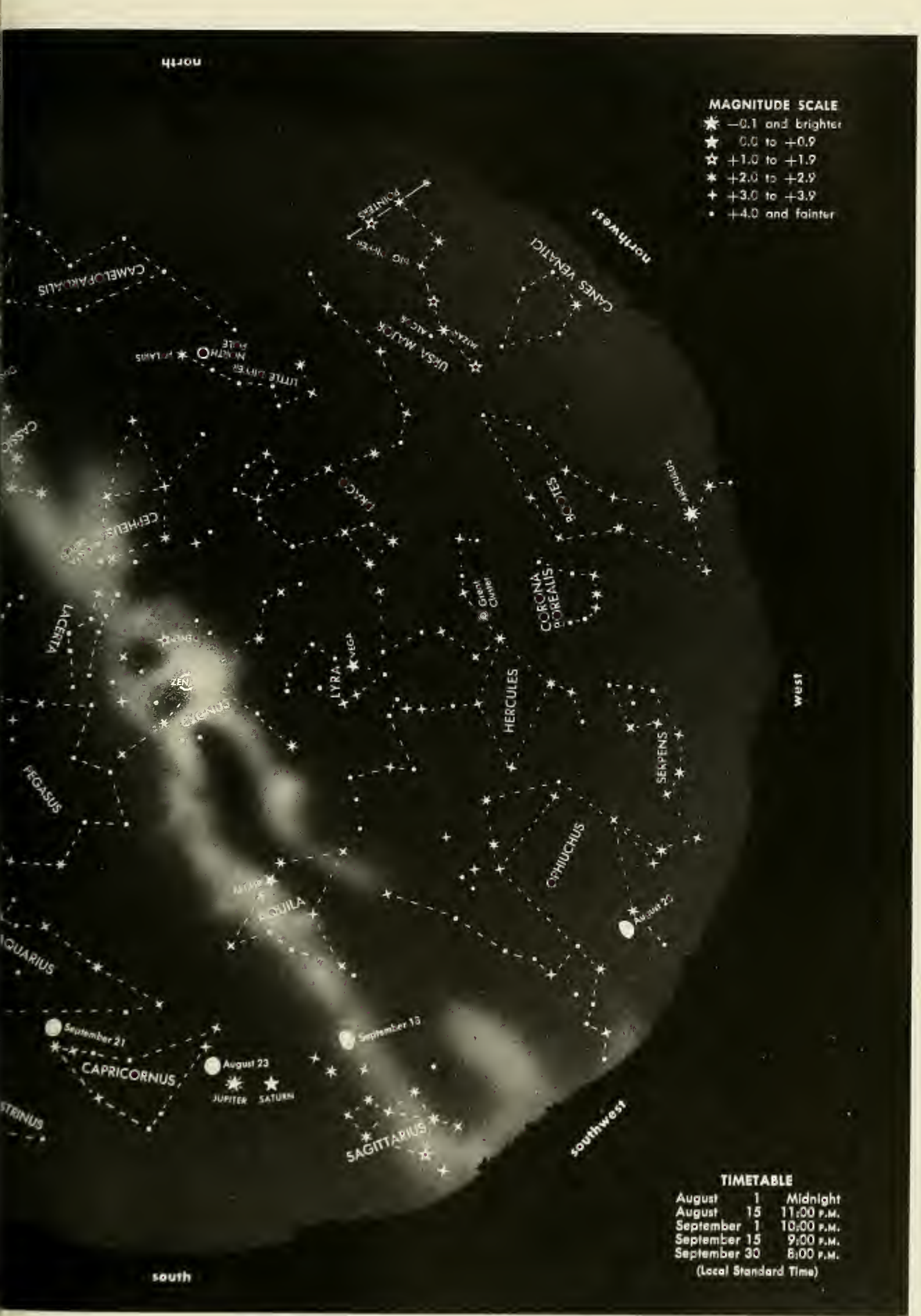
An annular eclipse of the sun will occur on August 11, but the path of the annular phase—in which the dark disk of the moon is seen surrounded by the bright rim of the sun—will lie entirely over the South Atlantic Ocean. Partial phases of the eclipse will be seen on the southeast coast of South America, in South Africa, and in Madagascar.

A nearly total eclipse of the moon will be visible in the continental United States on the evening of August 25, beginning at 8:35 P.M. and ending at 11:42 P.M., EST. On the West Coast, the moon will rise already partially eclipsed.

On the preceding pages, MRS. GOSSNER offers the seventh in her 1961 series on the growth of cosmological concepts.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.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POINTERS
BIG DIPPER
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ALCOR
MIZAR
CANES VENATICI
CASSIO
CEPHEUS
DRACO
BOOTES
ARCTURUS
CORONA BOREALIS
Great Cluster
HERCULES
LYRA
VEGA
DENEB
ZEN
CYGNUS
LACERTA
PEGASUS
SERPENS
OPHIUCHUS
ALTAIR
AQUILA
August 26
QUARIUS
September 21
CAPRICORNUS
August 23
JUPITER
SATURN
September 13
SAGITTARIUS
STRINUS

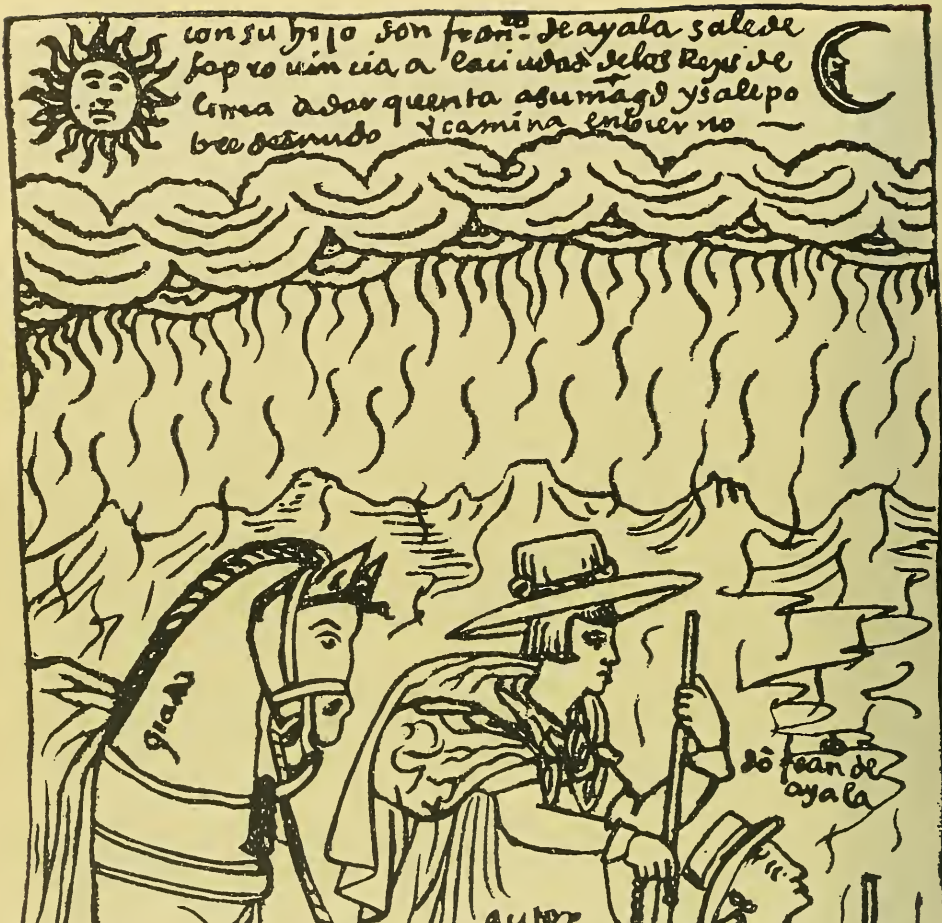
MAGNITUDE SCALE

✷	−0.1 and brighter
★	0.0 to +0.9
☆	+1.0 to +1.9
✶	+2.0 to +2.9
✦	+3.0 to +3.9
•	+4.0 and fainter

TIMETABLE

August	1	Midnight
August	15	11:00 P.M.
September	1	10:00 P.M.
September	15	9:00 P.M.
September	30	8:00 P.M.

(Local Standard Time)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GVAMAN POMA DE AYALA

A seventeenth-century Indian's account of Andean civilization

By John V. Murra

Of all the high civilizations of pre-Columbian America, that of the Incas has received the greater share of public attention. Here were not only civilized folk, with cities and temples, irrigation and kings, but also a utopian state that attracted curiosity from 1534 on, when the first European chroniclers began to publish their impressions in Seville. Here was a kingdom "where the government insured the individual against every sort of want and. in return, demanded heavy tribute. . . ." Over the years the notion has grown that Inca society, when met by the Europeans. was a kind of welfare. if not socialist. state.

Modern anthropology has been re-examining this commonplace in the light of recent ethnographic learning about similar transitional societies elsewhere. particularly those encountered in Africa and the Pacific.

These studies show that our vision of the Inca is distorted and that the blurring has been compounded because we see the Andean world through two alien lenses: that of the sixteenth-century European soldiers, priests, and administrators, and that of the Inca elite. who acted as the invaders' guides and confidants.

The most immediate limitation has been the absence of Andean versions of what the local peoples were like. We have no codices for the Andes like the Aztec, Zapotec, or Maya books written before the European invasion; no aboriginal writing has been discovered yet in South America. The political and intellectual decapitation of the Inca state by the Europeans was so swift that no interviews with the Amauta—the learned and reflective men—have been preserved. All we have are versions of the Cuzco court clique and the military. and even those were recorded imperfectly by impatient. ethnocentric strangers. Before us here is one of the few exceptions: a document about Andean man and his world written from the inside by one such man and illustrated by him with 400 drawings. This document is a unique source on Andean life before 1532.

Nobody knows how a 1.200-page "letter" by an Andean Indian, written to the King of Spain about 1615, found its way to Copenhagen. Some think it was in a collection of American curiosities bought in Madrid by a seventeenth-century Danish Ambassador; it remained unknown to students of the Inca for three centuries, until found in 1908 in the Royal Danish Library by Richard Pietschmann, a German scholar. Guamán Poma's manuscript, called *Nueva Corónica y Buen Gobierno* (the New Chronicle and [a] Good Government), was mostly a cry of anguish, a petition to the all-powerful King overseas to look at what his men were doing in America, to look at what they had destroyed.

Poma was born soon after the European invasion and grew up in the early decades of the colonial regime, a period of rapid decrease in the Indian population, years of civil wars among the invaders themselves, and of massive deportations to the silver mines of Potosí and Huancavelica. Much of his letter grieves for the vanished Andean order and complains of the iniquities of sixteenth-century colonization. But it is also a constructive document; most of it is devoted to plans for a "buen gobierno," a good government Poma thought could still be devised by combining revived Inca social and economic organization with Christianity and some beneficial aspects of European technology, such as growing grapes and making wine.

This article does not deal with Poma's dreams and plans for the future. It concentrates. instead. on the first third of the document, in which the Andean author tells the Spanish King of the glories of the pre-European past, the agricultural cycle of the peasant community and its relation to religious festivals, the distribution of chores and citizens' duties by sex and age, and the various ethnic and local groups submerged by the Inca conquest. He also provides a gallery of portraits and profiles of various Inca queens. victorious generals. and kings. Some of his facts are available from sources discovered and published before Poma; in fact, much information in these other sources is more detailed and more reliable than his. The Spanish used by other authors is more elegant, unmarred by the many Quechua words that pepper Poma's text. And yet there are two contributions he makes that are basic and have remained unequaled: the drawings supplementing

SELF-PORTRAIT OF THE AUTHOR shows Guamán Poma setting out for Lima with son, horse, and dogs, to deliver "letter" to Spanish viceroy. Poma lost all but his papers en route.

the text and his picture of what Inca civilization was like locally, away from Cuzco, the imperial capital.

Guamán Poma was aware of some of the books preceding his own. He had learned to read and write from a half-brother, a priest, and in later years he accompanied various clerics on their idol-burning missions through the Andes. With at least one of these missionary writers, Martín de Murúa, author of a history of the Inca kings, Poma had considerable contact: there are interesting parallels between the works of these two men they share with no other source. One of Poma's drawings has been found recently among Murúa's papers at the Apsley House Library in London. Poma's references to Fray Martín are bitter and sarcastic; his own work is titled *Nueva Corónica*, the *new* chronicle, to distinguish it from that of Fray Martín. Like other Peruvian Indian and half-Indian writers at the turn of the seventeenth century, Poma was moved to write his account not only because of his people's suffering but also because of the distortions that appeared in reports made by European observers.

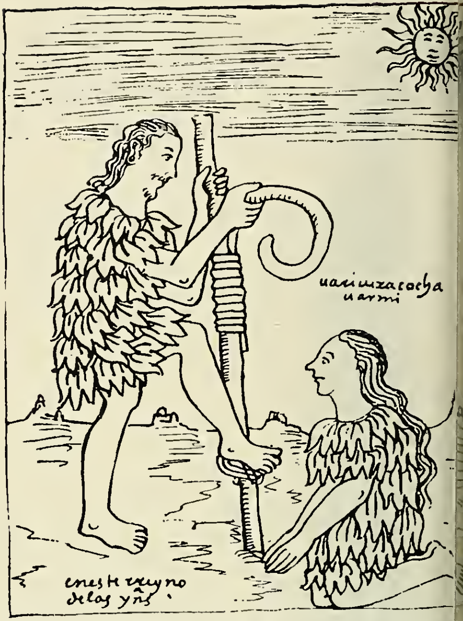
One of these distortions lay in the ready acceptance by Europeans of an Inca version of the pre-Incaic past. Although the Inca state had begun its expansion less than 100 years before 1532, Cuzco ideology claimed that all had been chaos and savagery in earlier days. Andean institutions were claimed to have been magnanimous grants to barbarians by the Cuzco crown. We know today from archeology that all this is untrue; for literally thousands of years before the Incas, people in the Andes had known how to irrigate the desert, make lovely tapestries and ceramics, and build fortresses, cities, and roads. All this was also known to many local lords and their descendants, defeated but recently by the Inca and still remembering their own past prominence and accomplishments. Poma claims direct descent from one of these local dynasties, the Yarovillcas of Huánuco; his book is meant to set the record straight in more ways than one—he promises us "the history of the first kings . . . of our ancestors, grandparents and my parents, who were lords before the Inca. . . ."

CIVILIZATION, Poma claims, is pre-Incaic. In a very personal amalgam of biblical legends with local Andean traditions, Poma sees a four-stage scheme that puts the descendants of Adam and Eve in America 7,000 years ago.

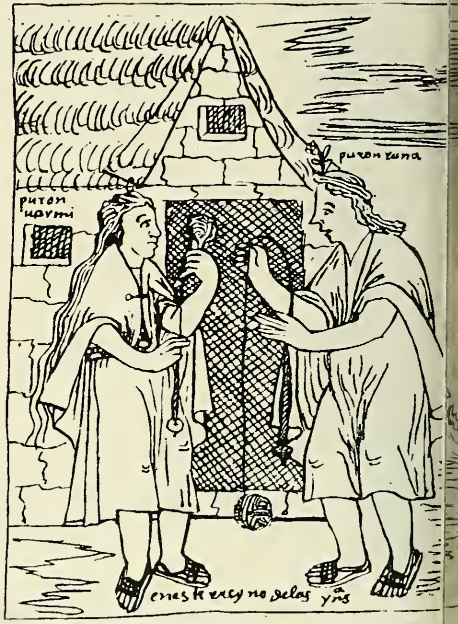
In the first stage, which lasted 800 years, the inhabitants—although already distinctly Indian—are still somewhat like "their father Adam"; like him they had "begun to work, to plow." But these early folk "did not know how to do anything," neither weave cloth nor build houses. They dressed in leaves and straw, and they lived in caves. Wandering through strange country, full of wild animals and dangerous spirits, "they lost their faith and hope in God, the word and commandment all was lost, and so they too were lost although they did have a small shadow of knowledge of the Creator of men and of the world and the sky, and Him they worshipped and called God. . . ." Throughout these four evolutionary stages this small shadow endures; it is only in the final, Inca period that idolatry and sun-worship make their appearance.

By the second stage, which lasted 1,300 years, men were dressed in furs and "they built small houses that looked like ovens." Agriculture had developed: terraces were built and irrigation brought water to the maize fields.

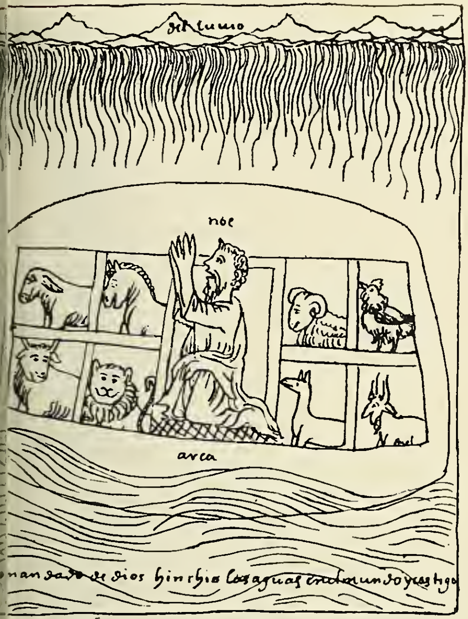
The third era was almost as long (1,100 years) and, in



First men, according to Poma, had basic agriculture bu
dressed in leaves. Their sparse beards linked them to Adam



Men in third stage of Poma's concept of human progre
could weave cloth and build stone houses with thatch roo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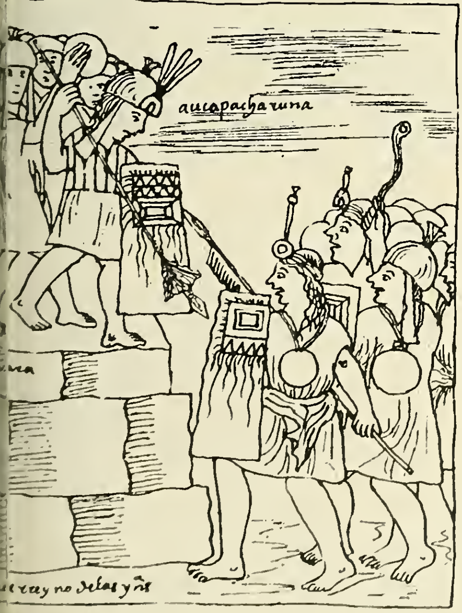
Noah's Ark, including a llama among the animals aboard, illustrates Poma's mixture of biblical, Andean traditions.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War was common in fourth period, although Poma points out that benefits devised in the third era still remained.

Poma's scheme, it is the most important. Men learned to weave both elegant and ordinary cloth; their houses were of stone with thatch roofs. The coast and other warm places were peopled, and "roads were opened for them, which one follows today." People raised many llamas and began looking for gold and silver. There was law and order; boundaries were marked on "properties and lands and pastures and maize fields." If the people proved to be varied in custom, language, and clothing, "it is because of the land which is so broken up and twisted." They raised kings and lords, "of the legitimate kind, descendant from the *uari uiracocha* people," of the first era. There was much charity in the land—"this is why they are in the public plaza" Poma writes of one picture—so all could partake of hospitality, and they sang and danced.

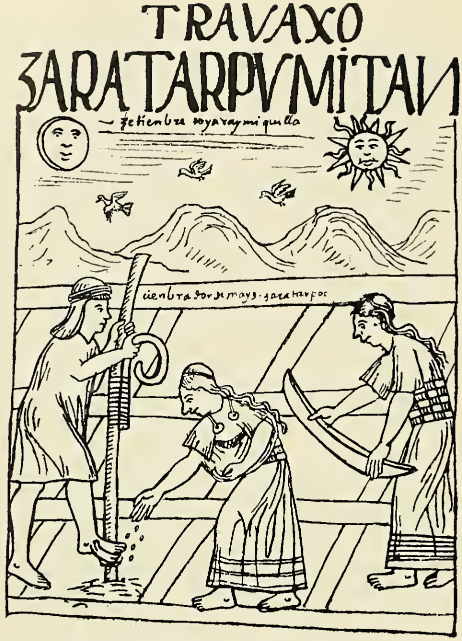
The description of this period ends with a prologue: "Look, Christian reader, look at these people, the third men. . . ." It was the start of a golden age in which, according to Poma, most of the accomplishments usually attributed to the Inca, particularly welfare features, were present long before Cuzco was even heard from.

The fourth period was the longest—it lasted 2,100 years. War became common and people had to withdraw to hilltops and build fortresses; they conquered each other's lands and took each other's women, and were led by valiant captains who could change themselves into lions and falcons. This is why today their descendants are called Guamán—falcon, and Poma—lion. The good system set up in the third era was still operative—"pilgrims and foreigners, orphans and the sick and those who had nothing to eat" could still eat in the public plaza—"no other nation has had this custom" and "if only they did not have these three vices—drunkenness and war and taking each other's lands away," one could think of them as "holy men."

It is in this fourth and last pre-Inca period that we meet the Yarovillca, whose descendant Guamán Poma claimed to be. Their home was near Huánuco but they reigned over vast territories beyond. Their ruler "had a higher crown" than others and even in later days "he was feared by the Inca. . . ." A genealogy is provided but the details are few, and we never learn how this mighty lord's descendants came to fall so low only a generation later.

After 5,300 years, these four ages of the world end with the ascendancy of the Inca dynasty in A.D. 300. Poma explains slyly the rise of idolatry and sun-worship at this time: the first Inca had no legitimate father, so his mother said he was an offspring of the Sun.

One of the most exciting accomplishments of Andean civilizations was their domestication of a wide variety of plants and animals well adapted to the extreme climate in the high Andes. The potato, the alpaca, the guinea pig, and the llama are well known, but scores of other plants—grains, roots, tubers, vegetables, and herbs—were also domesticated by Andean man, although they have not yet found acceptance in other parts of the world. At the extreme altitudes where man lives in these mountains, each change of 300 to 400 feet brings with it a new microclimate, and new crops must be found that survive the rigors of weather at 11,000 or even 13,000 feet and still bear fruit. Poma gives us a calendar of the agricultural practices. He shares the highlander's predilection for maize. Although maize is frequently very hard to grow at Andean



Planting maize in irrigated land marked September start of agricultural cycle. Major foods, however, were tubers.

altitudes, it had high prestige as a ceremonial food and as the main ingredient of *chicha*, a beer widely appreciated throughout the Andes. Potatoes and the other tubers may have been staples, but as a representative member of his culture, Poma deals mostly with maize.

The Andean peasant calendar began in the highlands during a month corresponding to parts of August and September, when the men broke ground with the *taklya* and the women sowed and hilled the earth. The inauguration of the cycle was also a festival with songs and dances: fasting, prayers, and sacrifices were also recommended. Both sun and moon appear frequently in Guamán Poma's pages since each affected the harvest. The special relationship believed to exist between the moon (heaven's queen) and women was celebrated at this time of the year, which Poma identifies as "the month of the queen's holiday."

Work *must* begin at this time says Poma, and "all [authorities] who will see this work" are urged to take care that early potatoes and maize be planted along with the slow-ripening varieties to make sure no one goes hungry while waiting for the major harvest, which in the high Andes is eight or nine months off.

In the second month, that of the September equinox, young maize shoots appeared, and so did the dangers that threatened this delicate crop: frosts, predatory animals, and drought. Parrots and other multicolored birds, attracted by the planting, were killed by boys with slingshots. Feathers harvested during such scarecrow duty were part of peasant obligations to the Inca state and were ser to state warehouses to be woven into soldiers' clothes.

The third period in the Andean calendar is called b Poma "the month of water shortages and the wate ing of maize." A warm-weather plant of general Ne World distribution, maize was particularly in need of art ficial watering: in fact, it can rarely ripen without irrig tion and in Andean circumstances requires a good deal special, almost gardening care. Poma reproduces fra ments of a prayer with which one supplemented irrigatio ". . . send me water from the skies, look at me your poc son, have compassion." There seems to be little relatio between the well or reservoir in his drawing and the lin forming squares on the ground in several of these picture It is nevertheless quite likely that the lines represent irr gation ditches, particularly as they are absent from h December drawing, which shows the planting of oca (*O alis tuberosa*), a major staple in the highlands. Potato and other locally domesticated tubers were grown witho irrigation on fallow land. They formed a separate an quite different type of Andean agriculture, readily disti guishable from that of maize. In this sense Poma's Decen ber illustration is an important bit of data—most earl writers were so obsessed with the difficulties and presti of growing maize that they virtually ignored local staple

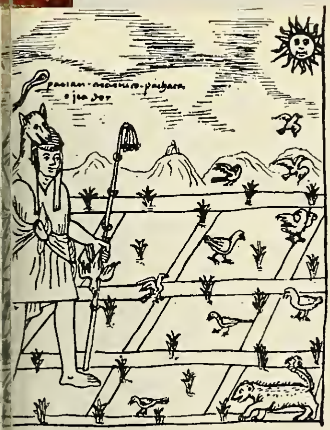
By January the rains are falling everywhere in the And and the growing plants must be hilled, while early potato can already be harvested. The rainy season has its ow dangers: food reserves are low and sickness is commo Poma writes that "the old and the children are dying. . .

In February and March, more of the tubers—the pea ant crop—can be harvested, and the corn is high and cob. Young people spend day and night in the fields guar ing the crops, which finally begin to ripen in April. Poma anxiety over crop theft reaches its peak this month sin human thieves join animals in threatening what wou otherwise be the beginning of a happy harvest season.

Aymuray—the song of the harvest—is the name of t next month, when the maize should be dried, husked, a deposited in warehouses, and "the seed kept and the be maize for food and the poorest for beer." In June, t larger potatoes can be dug up and the early ones plant to produce a third crop. Since the rains have stopped, t is also a good time to clean the irrigation ditches.

Poma's illustration for July showing deliveries to t warehouse, is less revealing than his text, which e phasizes an aspect of peasant agriculture in Inca tim that European writers have ignored: this was the "mon to exchange fields." This was an annual, ceremonial assertion of the community's rights over each famil land, which was felt to be only loaned to them. This a proach to *Mama Pacha*—Mother Earth—which treats la as inalienable community property, yet readily availa to all members of the kinship group on simple claim, c still be found today in remote corners of the Andean cha

One of Guamán Poma's principal aims in describing village activities in such detail was to show the Span King that Andean life was orderly, well organized, a governed by law. Here were no savages but a civilized ciety whose institutions deserved scrutiny and, Poma gued, even restoration to their original vigor. He liked dwell on the administrative orderliness of Inca life a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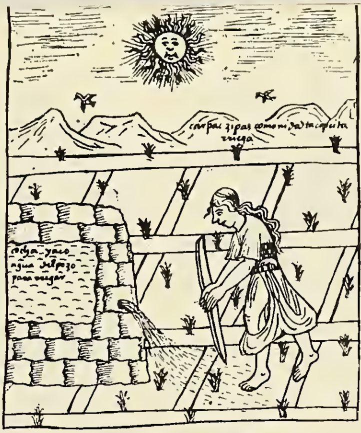
October: chase pests from field.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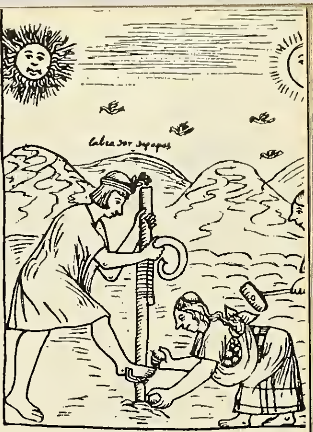
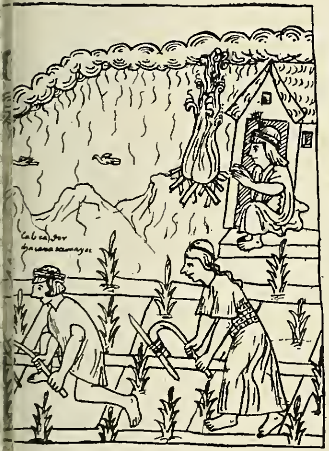
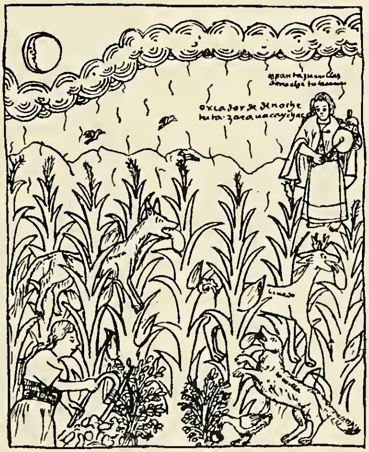
November: irrigate fields.


labrador sapapas

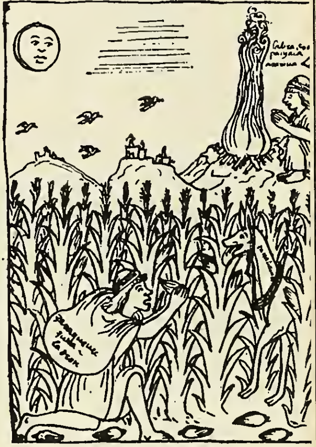
December: plant oca, a staple.

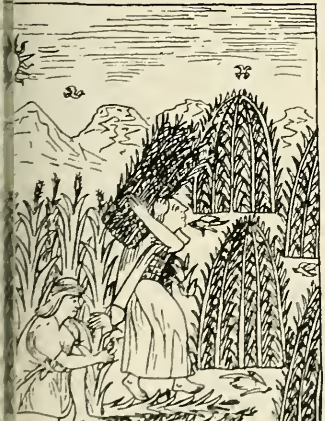

labrador
zaramamayoc

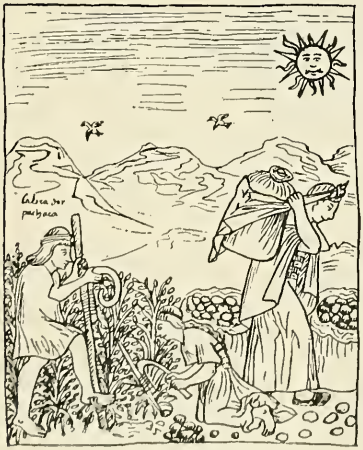
January: weed and hill corn.


oxeador de de noche
tuta zaraua caychac

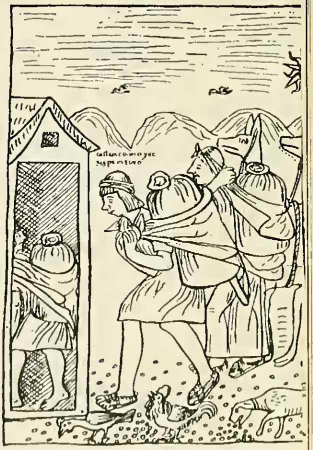
February: harvest early potatoes.


April: thieves attack crops.

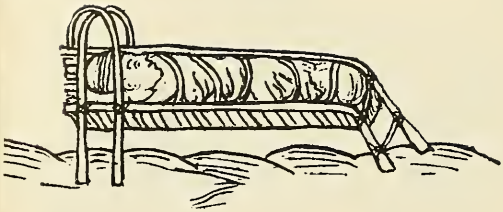

May: harvest the maize crop.

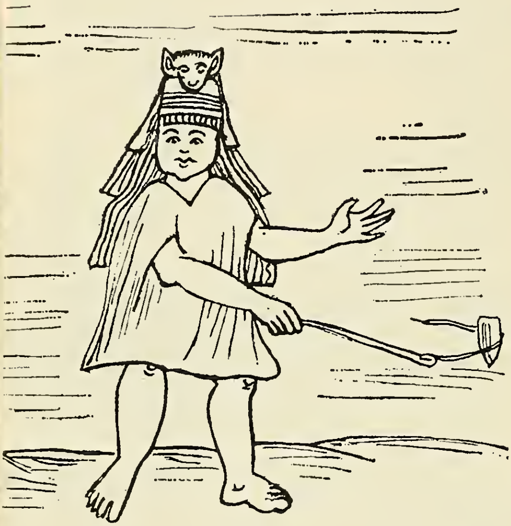

labrador
pachaca

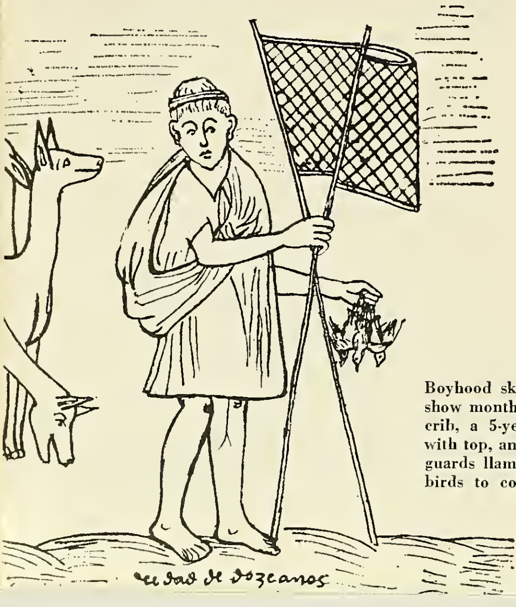
June: harvest the potatoes.


collcacamayoc
suspensivo

July: the crops are stored.







he saw in the census the visible symbol of this regularity.

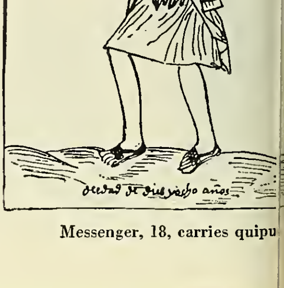
Poma's version of the Inca census is the best description available to us, in the view of Professor John H. Rowe, of Berkeley, who has made a special study of the census categories as recorded by various chroniclers. Poma does not distinguish between the local, village ways of classifying age and sex and those used by the Cuzco administration. Indeed, his categories are phrased in the decimal terminology preferred by the Inca administration but, as Rowe indicates, they are not far from the categories into which human life was classified by the common language. The actual ages are approximations; the villagers—and, eventually the state—were more interested in the function and status of the individual than in precise chronology.

Apparently the census was conducted periodically throughout the country, with people lined up in rows or "lanes" according to sex, age, and function. A separate knot-string record, the quipu, was kept for each group—twenty in all—and to each group Poma devotes a page. Some details concern homely household routines, but Poma is also aware of the census as being a device of authority, providing information useful to the state and local lords in formulating economic and military policy.

CLASSIFICATION begins with able-bodied mature women and men, already married, to whom Poma assigns an arbitrary age of thirty-three. In the text he broadens this to a range of twenty-five to fifty—a period inaugurated by marriage and closed when one's energies were failing. His description of this longest and most productive age emphasizes the man's obligation to fight in the kingdom's wars and to work at construction and mining. He takes man's perennial agricultural work for granted in this section; but he also neglects the major obligation of the citizen as seen by the Inca state: work on the crown estates—the main source of revenue for a state that collected no tribute in cash or kind but only in service.

Marriage, the threshold of this main category, is implicit in Poma's writing but is not detailed. This is "the first lane of the Indian women, married and widows . . . wed when they were thirty-three years old, until then they remained

Boyhood sketches, at left, show month-old baby in a crib, a 5-year-old playing with top, and a youth who guards llamas and catches birds to collect plumage.


edad de diez y ocho años

Messenger, 18, carries quipu

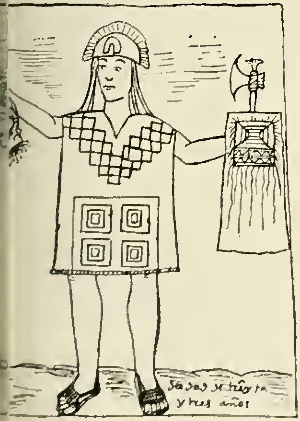
virgins and maiden. These said women, and also the said men, married at the same age and until then they called them children." It is very unlikely that marriage was delayed that long or that virginity was quite so prized. Under Inca rule, marriage was not just a personal turning point. It was an ingenious device of Inca statecraft to transform a once private action into a state matter: in fact, a taxation device. Only married men were required to provide their share of the state's revenues, their wedded personal maturity and responsibility being accepted as evidence of new status by the administrators at Cuzco.

Neglecting the woman as homemaker and gardener, Poma reflects Inca values when he stresses that "the said women had as their job the weaving of cloth, ordinary and thin, and spun thread for the fine fabrics." Just as every man farmed on the lands of the crown, so each woman—once married—owed a finished garment a year to the government. The fibers, cotton or wool, were provided from state warehouses, for the principle that no one owed the state anything from his own larder was applied quite consistently. In the second half of his letter Poma complains bitterly about European exactions of cloth, for which the Indians had to provide both labor and materials.

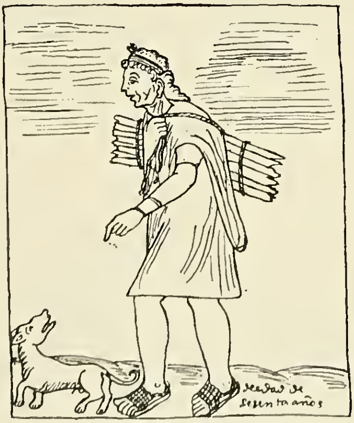
Poma's drawings for the second of life's lanes indicate an interesting contrast: whereas the fifty-year-old "woman and widow" continued at her weaving, the man in this age group was released from state military duties. While continuing to farm, such a man's state obligations now shifted to service for the *koraka*, the local lord. In a system such as the Inca, where every peasant household was essentially self-sufficient but was normally incorporated into a wider society that could not endure without the peasants' contribution, the local lord, like the king above him, could neither maintain his staff nor display expected hospitality without calling for contributions from his subects. In some cultures this contribution is in money, elsewhere in goods; but in the Inca realm these were unknown: the citizen—and in the local tribe, the member of the community—owed the authorities only some of his energy. How to apportion this energy between the various claimants was up to the local gentry. The *koraka* obviously found it easier to enforce his claim on those who were too young or too old for royal service.

WHAT life expectancy was in the Andes before the European invasion we cannot say. Poma often mentions kings who lived past 100, and his decimal arrangement of the ages of man allows for a third lane, to cover the old and deaf, "80 and up to 150 years old . . . who can only eat and sleep and, those who can, weave mats and rope . . . and raise guinea pigs and . . . ducks." Such failing energies did not bring isolation or destitution: ". . . they were much feared and honored . . . the whole village served them, these old men . . . and there was no need to have an old people's asylum since their fields were harvested for them and their llamas herded . . . and thus they had no need for charity. . . ." This system of permitting all hands, no matter how old or disabled, to own fields and pastures, worked for them by the community in a series of reciprocal services called *ayni* and *minka*, was in force also for the crippled or chronically ill, the mute, the hunchbacks, and the blind. In return, these persons rendered what services they could: "Those who had eyes were used to watch, those who had legs walked, those who had hands wove."

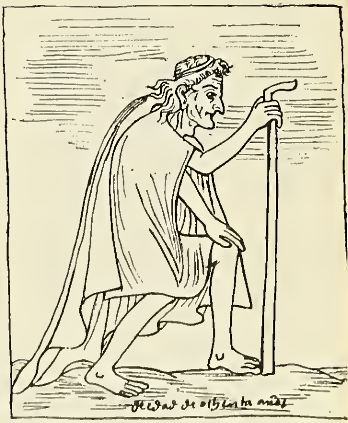
Poma is alone among chroniclers in telling us that the handicapped formed a separate, fourth lane in the census. He even claims that they were matched in marriage with others similarly disabled "so they would give birth and multiply, so there would be more of them so that the earth would not remain sterile, alone." This fear of the land's being barren and empty of people is an anxiety we find again and again in the prayers recorded for the Inca period. In a country where less than 2 per cent of the soil is cultivable and where frost is a danger in many places every night of the year, the notion that the handicapped person should *not* mate is unlikely to be popular. Spinsters and bachelors are rare in peasant and kinship societies. It is interesting that even Poma reflects the tendency to attribute to the Cuzco regime of A.D. 1500 a concern for welfare of the disabled. In reality, an individual's right to the good things in life, no matter what his physical



Warrior, 33, holds enemy head.



Man, 60, free of crown duties.



At 80, "deaf old man . . . sleepy."

condition, was an age-old custom in Andean cultures. This confusion between pre-Incaic institutions and their attribution to the Incas is only now being unraveled.

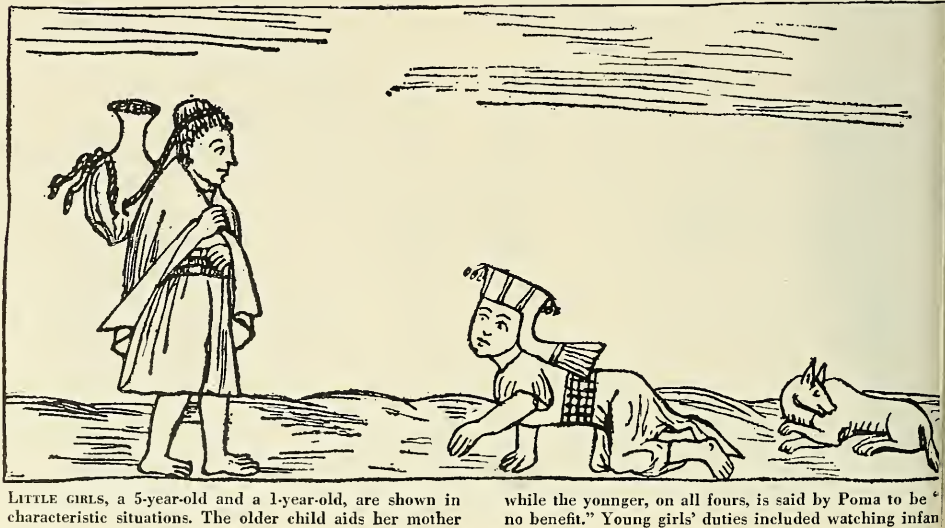
The remaining six lanes, or strings of the quipu, deal with youths of both sexes before marriage. Since they were exempt from major duties to the state, their lives were centered in the village. The twelve pages that Poma devotes to young people are thus used to record unique information about peasant life in the time of the Incas. In the years before marriage, roughly between eighteen and twenty-five, men were watchmen in the fields, herders, and messengers. In time of war they accompanied the armies, carrying food and other loads. Though not considered full-fledged citizens until they married, these were obviously able-bodied young men; thus, Poma's statements about them are startling: they were "virgins, who were ordered to eat raw corn, did not taste salt, nor chili peppers, no honey or vinegar, no sweets or meat, nor fattening things. [They] did not drink beer and [only] as a great gift did they give them a little hominy . . . nor did they know women in the entire kingdom." Few of the foods prohibited are indigenously Andean, and every one mentioned was actually taboo to some people at particular times. But we have no corroborative data from other sources that such restraints were universal for the young.

Curiously enough, such food prohibitions are not mentioned on the page dealing with girls ready to marry, although in an earlier passage *all* women were thus restricted. The young women's page deals primarily with the possibility of their being selected as *aklya*—the "chosen women"—"for the Sun and temples and the Moon and Morning Star and for the Inca and for the Gods . . . the said women served in everything ordered by the Inca and justice." Since it is unlikely that the average woman observed all these food taboos routinely and since, in the case of men, Poma seems to generalize about practices that were actually occasional and ceremonial, one wonders if here again our author were not so much wrong as eager to attribute to all Andean women what was really th ritual and intermittent behavior of the *aklya*. His motivation for such distortion can be glimpsed in the closing lines of the page describing the young women: "everything bad, adultery and other mortal sins were brought with them by the said Christians. . . ."

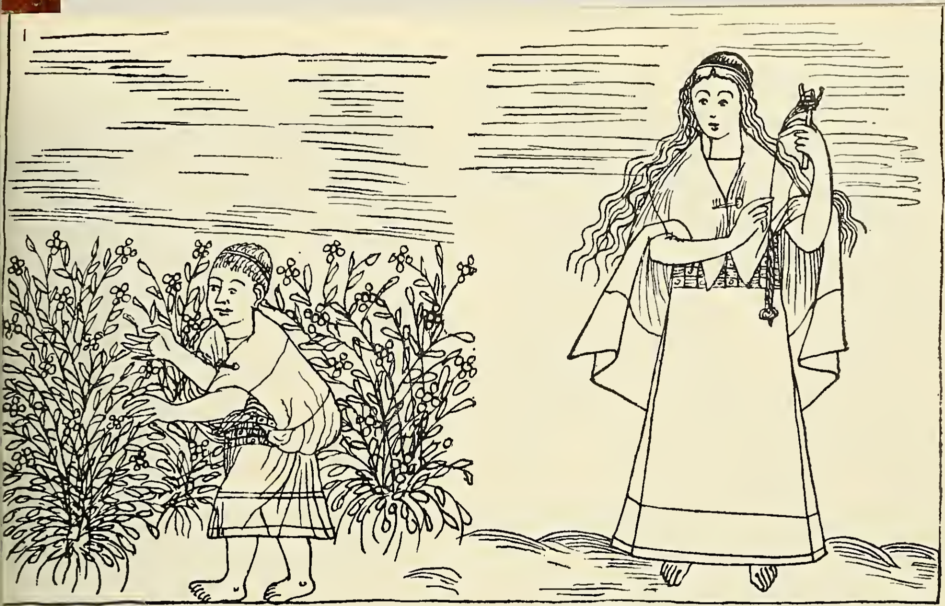
Adolescents helped their parents with herding, farming weaving, and cooking. Their one obligation to the state has already been mentioned—catching brightly colored birds for their feathers, owed to the crown. This task seems to contradict the principle—no tribute in kind but only in energy—that was the heart of the government's revenue system. Actually, in Inca thinking, wild, uncultivated resources such as game, lumber, and parrot feathers were a crown monopoly since no local community could be said to own them. Ownership in Andean ideology—and this is likely to have been true even before the Inca—was related closely to cultivation and the subsistence it permitted

At adolescence, the males also began to run errands fo the local gentry, and such services made Guamá Poma reflect that "before there were Incas, each villag had its own Inca and king, a lord to be served and thes boys were a help [to them] and to the communities. . . Adolescent girls learned "to spin and weave delicate thing . . . they walked without elegance and barefoot and thei clothing was short. They served their father and mothe very much . . . and had much obedience and respect. . . They also picked flowers for dyes." Domestic duties bega even earlier for girls than for boys. It is interesting t contrast the five-year-old girl, fetching water, with the bo of the same age, who is spinning a top, although in th text accompanying the drawings they are not so far apar —both "helped in what they could" and both played

Another noticeable contrast between picture and text found in the animal headdress worn by the five- to nin year-old boy, also seen in some of the agricultural drawings. There is no reference in the text to such pre-Europea



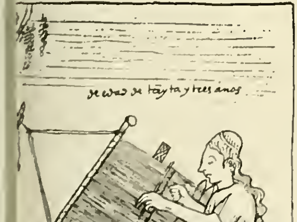
Little girls, a 5-year-old and a 1-year-old, are shown in characteristic situations. The older child aids her mother while the younger, on all fours, is said by Poma to be " no benefit." Young girls' duties included watching infan



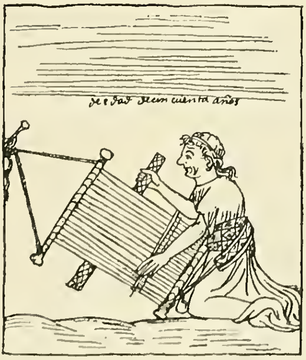
ICKING FLOWERS for dyes is the task of 9-year-old girl and pinning thread occupies young woman "of marriageable age." Making cloth was of great concern to women of Andes, who, after marriage, owed the government a garment a year.

ractices as the wearing of symbolic or ritual headdresses. The last two lanes enumerate children so small "they re for nothing [can do no work]. They should be served y others and be played with by another child who should e they do not fall, nor get burned, to watch him well. . . . is very right that his mother be freed [from other uties] for the children and if he is an orphan much ore and if two be born from the same womb their mother nd father should be freed for two years . . . a very old law this kingdom . . . which the Incas ordered to be kept . . there was no need for so much charity when they pt these orders." Another ordinance Poma liked was at from the moment the child "left her mother's womb e was assigned lands and fields and they were worked by] her kindred . . . even if she had father and mother." his. he noted. also avoided the need for charity. Such desirable measures, Guamán Poma added ironically, "they have not had in Castile. nor will they have them."

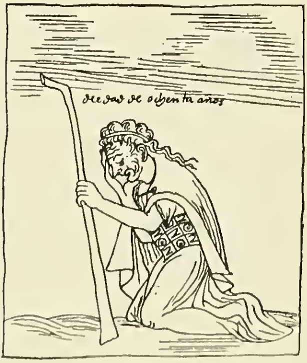
THE reason Poma thought Europeans would keep relying on charity instead of automatic welfare institutions like those he grew up with in the Andes deserves attention: "They [the Europeans] are roguish people, who from common men want to be lords, [coming] from poor lineage they want to be kings, to which they are not entitled by right of lineage or blood. . . ." Faced with the social and economic opportunities and aspirations that the invasion of the Andes made possible for invading Europeans, Poma retreats into what Dr. Raul Porras Barrenechea, a leading modern Peruvian historian, has called an aristocratic pose. Poma knew that many invaders were nobodies in the feudal world they came from; that


de edad de tayta y tres años

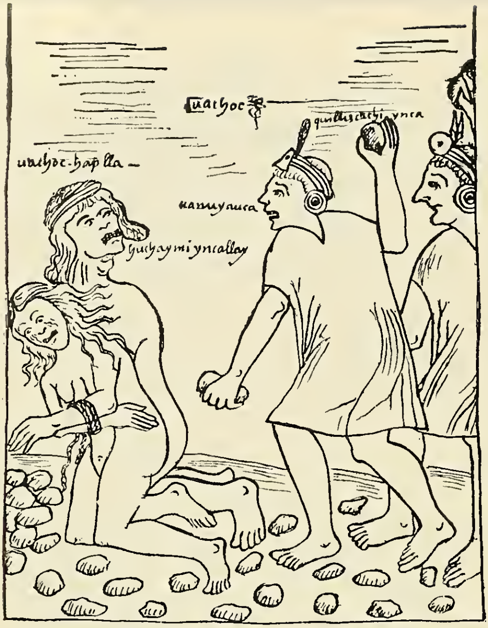
Soldier's wife, 33 at loom.


de edad de cincuenta años

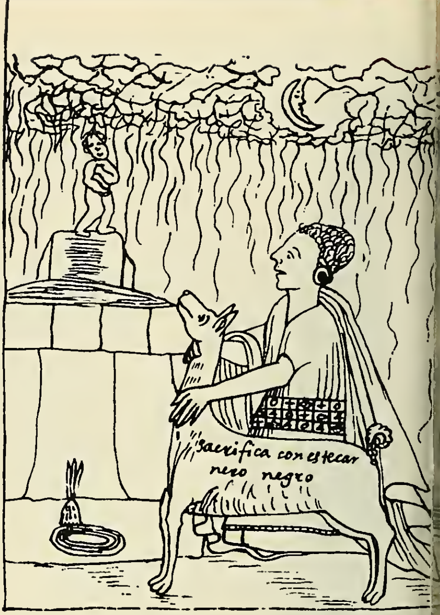
Woman, 50, weaves for gentry.


de edad de ochenta años

At age of 80, woman rests.



Adulterous couple is stoned by an official, who shouts at the man, "Die traitor!" Poma's depiction of adultery as state crime and sin may well be distortion or exaggeration.



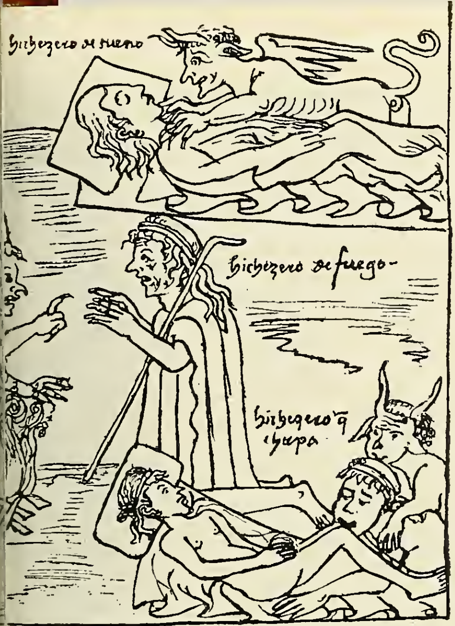
Black llama is sacrificed during rainy season, in Ma
Although Europeans crushed Inca church shortly after 1
religion has survived along with many rituals and spe

they put risk and opportunity ahead of established rank and privilege; that he, on the contrary, was the grandson of an Inca viceroy come to little. But one can say that Poma was aware of the systemic differences between the European and Andean societies: in the latter there was no need for charity because the welfare features were built in. No one was poor because no one could be deprived of what today we call capital goods: lands, herds, and access to the reciprocal services of others, particularly one's kinfolk. This was no longer true of Europe.

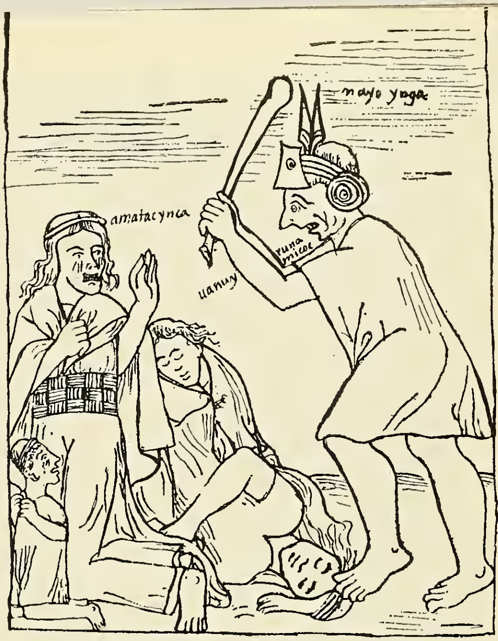
No place for deviation from the ideal norm exists in Poma's system. The Andean world was well organized, according to him, and this was adequate to deter wrongdoing: "this justice and law they had in the whole kingdom and they were punished by the governors, *tocricoc*, and judges, *michoc* . . . and . . . there were no murderers, nor lawsuits, nor lies, nor petitions, no court officials, nor thieves. . . ." This idyllic picture need not detain us, since we have already seen among the agricultural drawings the thief stealing the new corn. We know from other sources that local headmen had permanent court functions and that litigation between communities over water and pasture rights was common. But Poma himself gives us information elsewhere, where he is eager to show the civilized nature of the Inca world, that gives a truer story: "punishment of lazy ones and dirty and pigs who own nothing clean, with dirty hair and faces and smelly mouths . . . and clothing, they were punished with one hundred lashes with a sling. . . ."

Dr. Sally Moore, a lawyer and anthropologist, made a study of Inca law recently—a difficult task, indeed, since there was no Inca writing and thus no record of court proceedings or legislation. It is particularly difficult to separate the various local ethnic norms from the Inca dec s dictated in Cuzco, but apparently in both systems pun ment was direct and corporal: whipping, torture, ston and the death penalty prevailed. In contrast, there w e few fines and virtually no jails. There must also h e existed many less formal mechanisms of social contro n the peasant community, such as shaming or ostracism o enforce the cultural ideal. Most of these have been los

Of all misdeeds and deviations, those of a sexual na e obsessed Poma. Many of the pages and illustrations in e second half of his manuscript, which deals with colo al times, return to the disintegration of Andean standards der the blows of European occupation. Rape and seduc n of Andean women by the invaders were not only a m social problem in the sixteenth century but also, inevita a personal concern. Recall that one of Poma's broth s. the priest who educated him, had a European father. e story behind this is never explained in Poma's docum t. In contrast to such contemporary reality, the Inca st assumes in Poma's eyes orderly and virtuous proporti s. Not only were men and women chaste until marriage as we have seen, but Poma has also classified all devia n from such chastity as adultery and made of it a te crime and a sin. "If the man forces the woman, he is n-tenced to death and she to two hundred lashes with a e and exile to the house of the *aklya*, the chosen wo n. where she will serve all her life . . . if the woman forc e man, she is sentenced to death and he to the lashes d exile to the jungle, to the Chuncho Indians so he ill never appear again and if they both agreed they both ie and will not be buried and they will be eaten by vult es and foxes and their bones will lie about on the grou ." There is obviously much fantasy in this vision of ca intervention into marital matters, although it is not n-



HREE MEDICINE MEN demonstrate their specialties: talking the devil while dreaming, at top; summoning the devil hrough fire, at center; and sucking illness from patient.

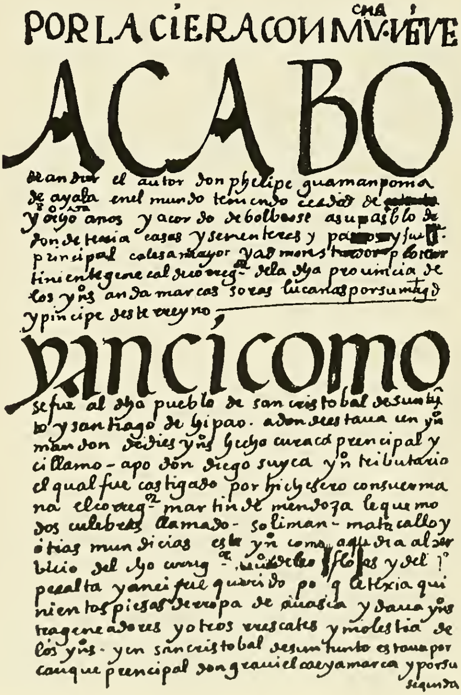


Murder by witchcraft brought death penalty to witch's whole family except nursing infants, who had not learned "trade." An example of author's calligraphy is seen below.

kely that there were community measures that went eyond revenge by the injured party in cases of adultery.

Another of the areas of Andean culture where Poma's formation is both exasperatingly patchy and frequently evealing is that of religion. We still know very little bout peasant belief and practices, since most chroniclers ealt only with the state church and its sumptuous ceremonials in Cuzco. Only toward the end of the sixteenth ntury is there a change of emphasis: we begin to hear of cal cults, of village folk resisting relocation away from icestral shrines, of differences in burial customs from ovince to province. At this time the European clergy, sembled in conclave in Lima, complained that heathen actices endured everywhere although the Indians had en converted and baptized for fifty years. Much as in icatan, where Bishop Diego de Landa (who burned the aya scrolls) is our chief source on Maya culture, so in ru the persecutors of Andean religions have often left tailed, valuable accounts of that which they destroyed.

WE gather from other writers that much of Andean peasant religion centered on agricultural ritual. hereas the state church was primarily concerned with iize, local shrines and deities shared their parishioners' xiety about the staple tuber crops. Many activities— h as herding llamas, clearing irrigation ditches, nurtur- g avocado pears, or gathering coca leaves—were defined the Andes as religious endeavors, although the real- ic efforts that accompanied them to ensure a food pply were never neglected. Sacrifices and libations were integral part of the rites, particularly when catastrophes eatened the world of man. Foodstuffs, cloth, llamas, d, in great emergencies, even humans could be offered propitiation. At moments of great crisis, black llamas



POR LA CIERA CON MV[CHA] BREVE

ACABO

dando el autor don phelipe guamanpoma
de ayala enel mundo teniendo edad de ~~[illegible]~~
ochenta anos y acordo de bolberse asu pueblo de
donde tenia casas y sementeras y pa[illegible] y fue
principal cacique mayor y admenistrador p[illegible]
tiniente general del correg^dor dela dha prouincia de
los yns andamarcas soras lucanas por su mag^d
y pincipe deste reyno,

y anci como

se fue al dho pueblo de san cristobal de sunto
y santiago de chipao. adonde estaua un yn
mandon [illegible] yns hecho curaca prencipal y
ci llamo - apo don diego suyca yn tributario
el qual fue castigado por hichesero con su erma
na elcorreg^or martin de mendoza le quemo
dos culebras llamado - soliman - matacallo y
otras mundicias este yn como [illegible] al ser
uicio del dho correg^or [illegible] flores y del [illegible]
pecalta y anci fue querido por q le traxia qui
nientos piesas de ropa de auasca y daua yns
tragenadores y otros rescates y molestia de
los yns - y en san cristobal de sunto estaua por
cacique prencipal don grauiel caeyamarca y por su
segunda

Dr. Murra, Professor of Anthropology at Vassar College, has made intensive studies of Andean life. The second part of his article about Poma's Peru will appear in October.

and black dogs were beaten in order to attract the attention of the deity by means of their cries.

The Europeans destroyed the Inca church very soon after 1532 and also persecuted the local cults. Yet, like Andean agriculture, Andean religion has managed to endure until today, and many of the rituals and spells Poma describes can still be studied in the Andes. Despite his pro-European bias in religious matters, Poma had good knowledge of traditional beliefs, possibly because of his idol-burning activities. Frequently he gives unique data about the shamans, all of whom he calls witches, but whose functions and talents he differentiates soundly. There were, for example, "witches who slept and between dreams talk to the devils and tell them . . . all that is happening and all they want and ask for. There are dream witches and when they wake they sacrifice to and adore the devils. These are witches of subtle secrets. . . ."

Other witches spoke "with devils and such and say that they suck out illness from the body and they take out coins or a stone or sticks and worms or a frog or a kernel of corn from the body. . . ." Still other witches, says Poma, "take a toad, remove the poison from a snake and they say they talk with them and poison people. . . . They take the toad and sew up its mouth and eyes with thorns and they tie up the toad's hands and feet and they bury it in a place where the enemy or the ill-wisher is likely to sit down so that he will suffer and die there, like the toad who does not die but it suffers. . . ."

Elsewhere in his letter Poma tells us how murder through witchcraft was punished: "those who give poisonous draughts and venoms that kill the Indians . . . who keep toads and birds to kill people . . . these Indians were killed . . . with all their caste and kindred and their sons and grandsons, escaping only the children who were still suckled since they did not know the trade and thus they escaped death. These [dead] were not buried but left to be eaten by condors and vultures and foxes in the field. . . ." The destruction of a man's whole lineage is reported by other sources in cases of rebellion and treason. Always in favor of orderliness, Poma may again be guilty, here, of extending the range of punishable behavior to meet potential European criticism.

Although he lived in various parts of Peru in his youth and visited other areas while in the service of the clergy, Poma shows relatively little knowledge of or interest in the variety of cultures and customs prevalent in the Andes. He was narrowly patriotic: the people of his own region, who "although they are Indians small in body, are brave in warfare because they ate maize and drank maize beer which gives strength . . . and puts them ahead in the kingdom . . ." are contrasted to the Kolla, dwellers in the high Southern Andes, who ". . . were Indians of very little strength and courage . . . fat, suety and good for little since they eat potatoes and drink potato beer."

Although such stereotyped notions about the various pre-Inca ethnic groups are numerous in his work, Poma shows more sensitivity to real differences when dealing with death. He devoted nine pages to mortuary customs, and one senses that here was a topic about which he was well informed. The Kolla people of the South "dressed [the corpse] and mourned him on the first day and on the fifth day they bury him sitting, with much clothing and pottery. If he was a poor Indian he is brought much food by his father and mother and the relatives and brothers and friends send him food or beer . . . and with this they bury the dead on the fifth day . . . and on the tenth day they mourn him again and send as many gifts and then they burn him and when the flame of the fire crackles they say he is received by the dead ones and they go directly to *Acaraypampa*, the plain of the dead . . . and they say tha there is much festivity there and conversation among the dead male and the women . . . and so they bury them with their food and drink and always they take care to send them to eat and to drink. . . ."

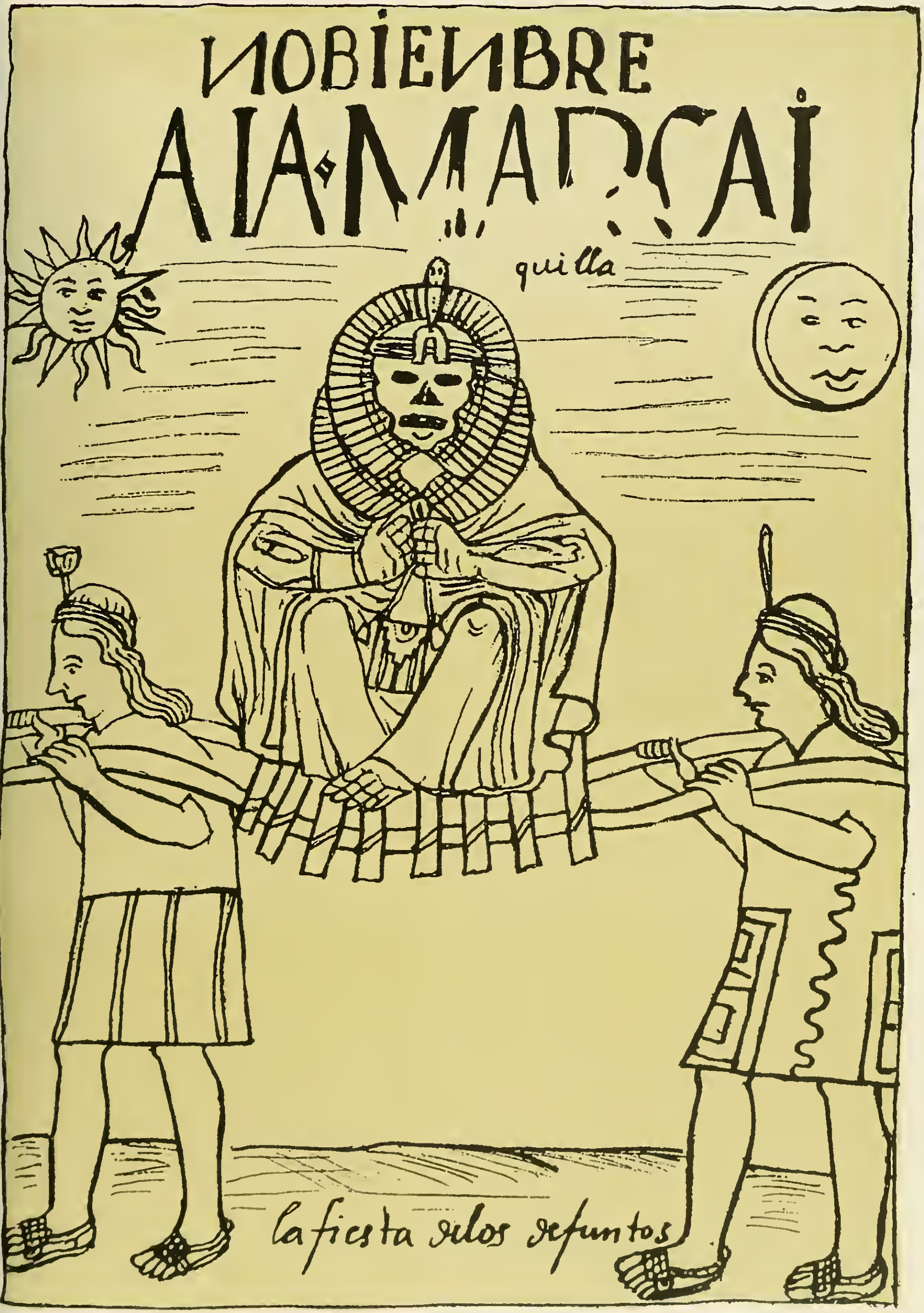
In his own area, farther north, Poma reports that "on the fifth night after death they held a wake and they fasted not eating salt and other dainties. Then they killed a llama and they ate it raw or cooked but without salt o chili peppers and they made a dish with potatoes and raw blood and they feed the dead one . . . and they weep and sing their songs and dances . . . and they shout and cry and he who cries most, that one drinks more and get more meat and the woman who sings and has a good voic for weeping she receives a leg of llama . . . and the dead one is washed and they dress him in all his clothes and feathers and jewels . . . and they put him on a litter and they go in procession. . . . They sing and follow him jumping and each lineage goes weeping and they bur him. . . . The good widow makes these ceremonies last tw years and on each anniversary [there is] much preaching from the old Indians. . . ."

One wonders why Poma displayed so much interest i death, to the exclusion of other religious and life cycl activities. Beyond his personal anxieties about death an his unpreparedness for it according to local standards-something we cannot plumb at this distance—one explan ation could be his share in the campaign to "root out ido atry" that centered on the visible rites surviving five o six decades after the European invasion. After 1572, whe Viceroy de Toledo began to resettle people forcibl throughout the Andes to facilitate tax-collecting and con trol, it became obvious that villagers were greatly a tached to their cemeteries and it took a major effort t keep them away from their traditional settlements.

Poma's picture of the Andean village is obviously in complete and often contradictory. A man of truly tran sitional times, Poma found himself condemning on som pages the very things he had praised elsewhere. But h native testimony remains of enormous value to those in terested in how Andean Indians reacted to the invasio of their country and to the destruction of their cultur In the history of European colonization the world ove there are few documents from any native's pen so d tailed, so genuine, and so revealing. Guamán Poma's lon lost chronicle manages to contribute at one and the sam time to Andean anthropology, to the history of moder Peru, and to our understanding of the life of colonized man

(*To be concluded in October*)

Festival of the dead was in November, the month of th dead. Skeletons were taken from vault, given food, dresse in new clothes, and taken from house to house on a litte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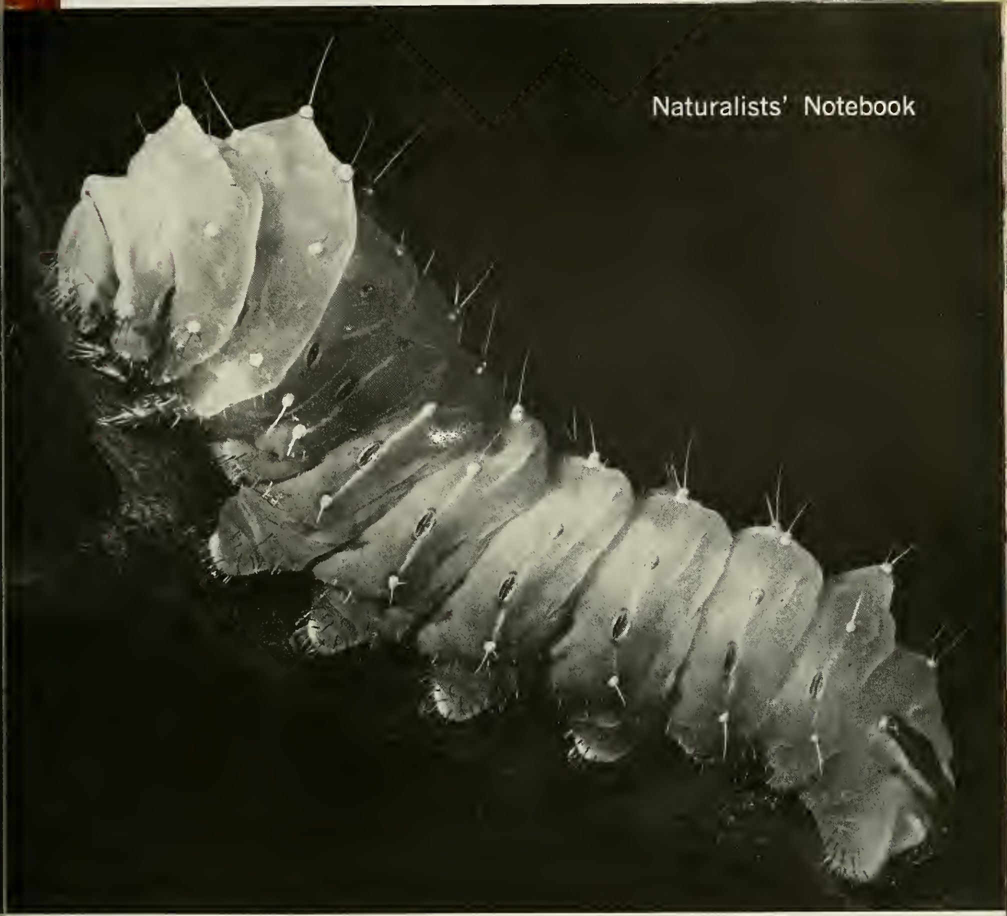


Caterpillar of polyphemus moth is clear green and has raised, silvery-white lines on side. Larva feeds on oak, birch, and other trees, finally spins a cocoon that contains a long and unbroken thread of silk.

THE COLORFUL POLYPHEMUS

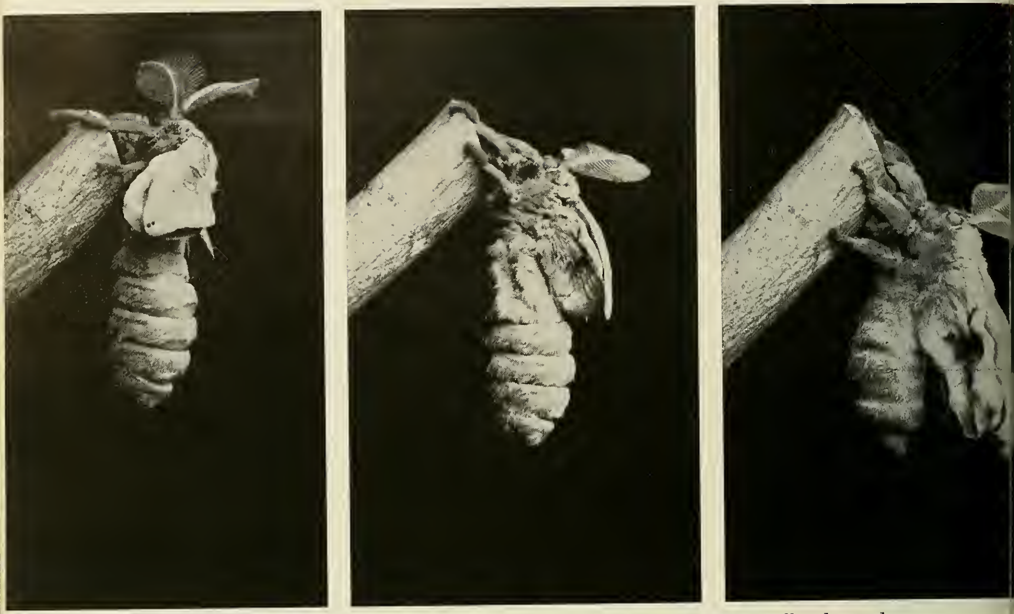
multihued moth begins its life as a bright green caterpillar

Photographs by H. Lou Gibson

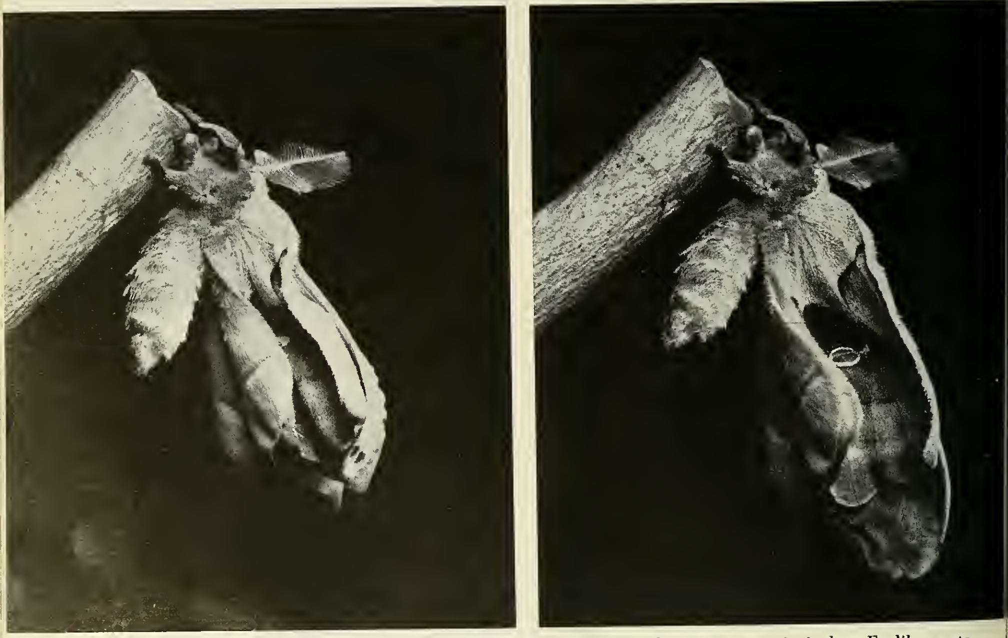
According to Greek myth, Polyphemus was a one-eyed giant who iprisoned and was subsequently nded by Odysseus. His namesake is other giant, formally known as *theraea polyphemus* — a silkworm th of the family Saturniidae, which ludes the largest of the Lepidoptera. The polyphemus moth is a New orld species that ranges through the ited States and into Mexico. The cordion-bodied caterpillar is a magnificent clear green, sometimes tinted with a bluish cast. After a series of molts, the larva leaves the food plant and finds a place to pupate. The dense cocoon it spins is attached to a twig or, on occasion, rolled up neatly in a leaf. When the cocoon is completed, the encased caterpillar releases a fluid that soaks through the silk and hardens, "winterizing" the structure.

In early spring the spectacular adult moths struggle free of the cocoon, and spend the rest of their brief life mating and laying eggs. As an adult, the polyphemus does not eat. During its larval life it has stored fat, which continues to nourish it during the pupation period and while it makes its nuptial flights at twilight.

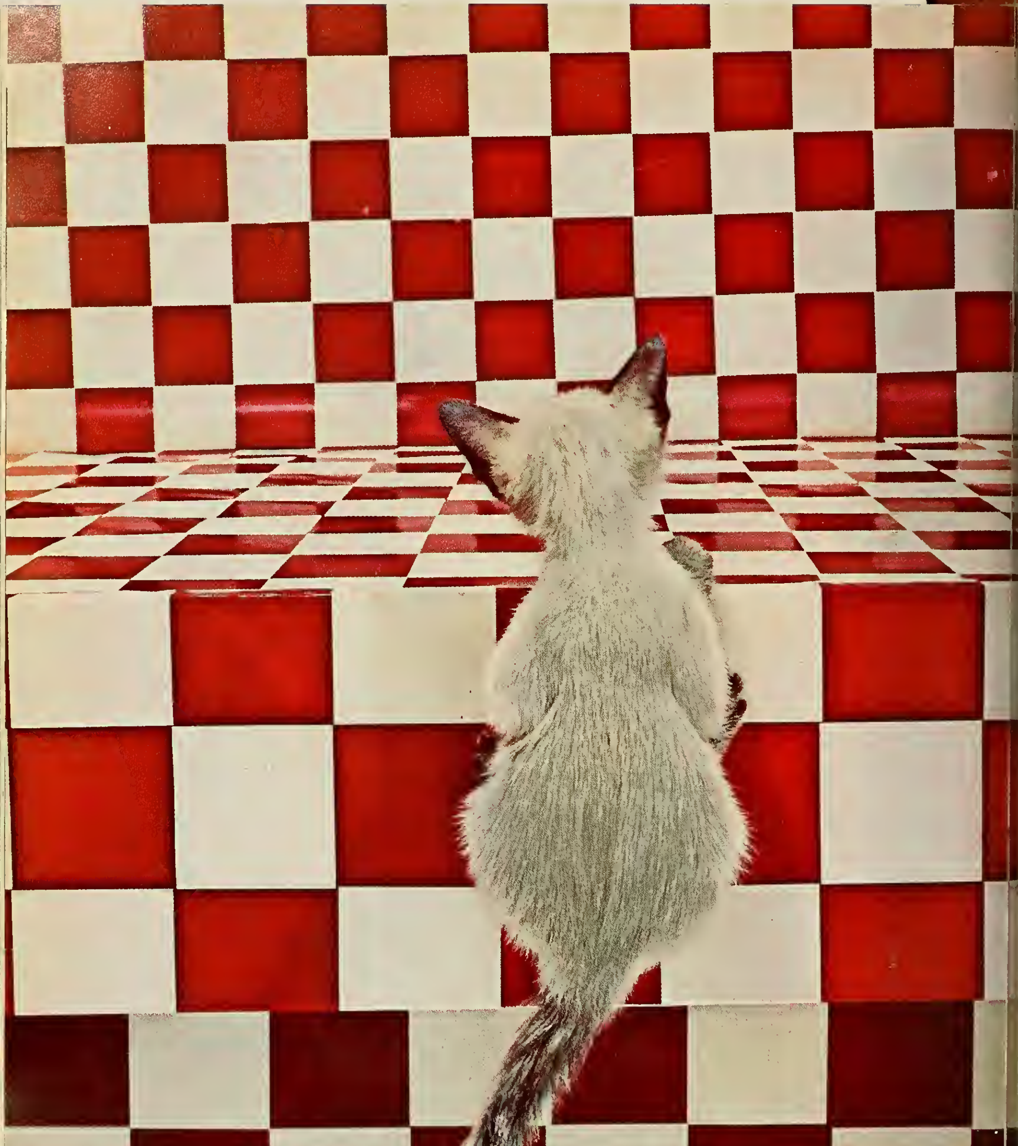
So marginal is the adult life of this moth that it is not unusual for the female to fall dead at the base of the very plant on which, seconds before, she had deposited the last of her eggs.



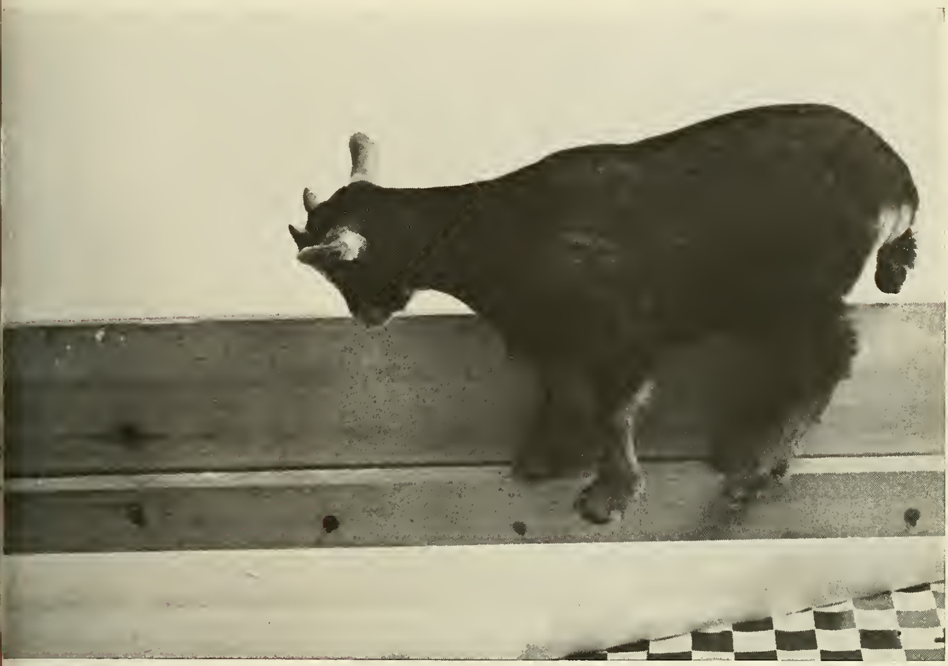
After emerging from cocoon in late spring, the adult moth begins expansion of its wings. As the veins are pumped full, the wings unroll and spread, as shown, from left. The process requires several hours.



Toward the end of the expansion period, wings become prominent, finally gain full size, *right*. Spread of wings may be as great as six inches. Eyelike spots on the hind wings may serve to confuse enemies.



PEERING OVER "CLIFF," kitten resists leaving board that spans glass in laboratory test of depth perception. One of two visual cues is clearly demonstrated here: phenomenon of size and spacing of patterns that decrease with distance.



ONLY ONE DAY OLD, kid already exhibits its capacity for depth perception as it huddles by side of test frame to avoid the "chasm" beneath. Despite the fact that kid stands on solid glass, its "sense of danger" depends more on visual cues.

Crossing Visual Cliffs

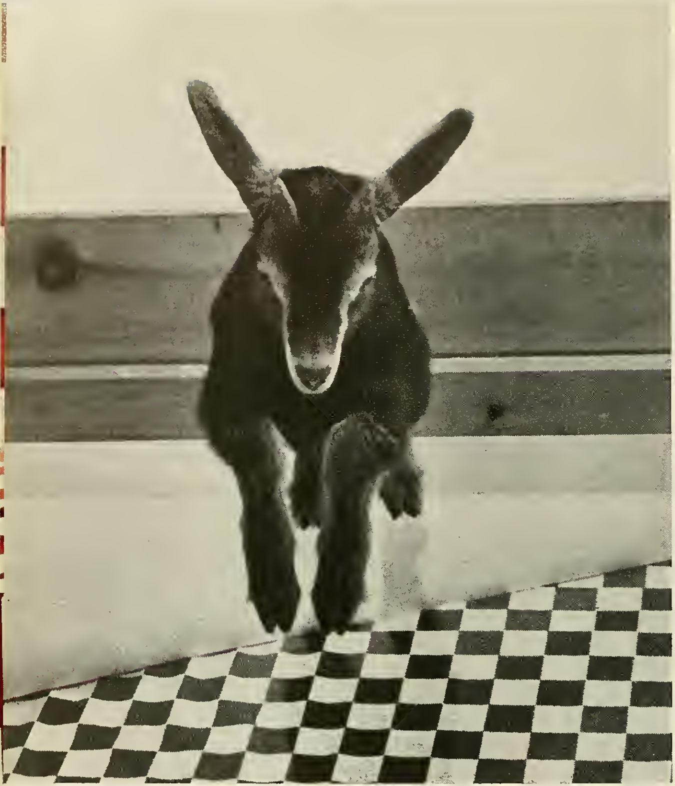
Depth perception in animals is tested by control of optical cues

By ELEANOR J. GIBSON and RICHARD D. WALK

HUMAN INFANTS at the creeping and toddling stage are notoriously prone to falls from more or less high laces. They must be kept from going over the brink by ide panels on their cribs, gates on stairways, and the vigilnce of adults. But as their muscular co-ordination maures, they begin to avoid such accidents on their own. ow, common sense might suggest that a child learns to ecognize falling-off places by experience—that is, by lling and hurting himself. But is experience really the eacher? Or is the ability to perceive and avoid a brink part f the child's original endowment?

At Cornell University, we have been investigating these roblems by means of a simple experimental setup that we ll a "visual cliff." The cliff is a simulated one and hence akes it possible not only to control the optical and other imuli (auditory and tactual, for instance) but also to rotect the experimental subjects. It consists of a board id across a large sheet of heavy glass that is supported a foot or more above the floor. On one side of the board, a sheet of patterned material is placed flush against the undersurface of the glass, giving the glass the appearance of solidity as well as the substance. On the other side, a sheet of the same material is laid upon the floor: this side of the board thus becomes the visual cliff.

We tested thirty-six infants, ranging in age from six months to fourteen months, on the visual cliff. Each child was placed upon the center board, and his mother called him to her from the "cliff" side and the "shallow" side successively. Twenty-seven infants moved off the board. They all crawled out on the shallow side at least once, while only three crept off the "brink" onto the glass over the cliff. Many of the infants crawled away from the mother when she called to them from the cliff side; others cried when she stood there, because they could not come to her without crossing an apparent chasm. The experiment thus demonstrated that most human infants can dis-



Kid leaps chasm to safety of the center. Survival of the species requires that an individual develop discrimination by time it is ready to take up locomotion.

Forelegs reach support in center as kid springs "safely" onto shallow side.

criminate depth as soon as they can crawl. It also gave clear evidence of their dependence on vision: often, they would peer down through the glass on the deep side and then back away. Others patted the glass with their hands, yet—despite this tactual assurance refused to cross.

This experiment does *not* prove that the human infant's perception and avoidance of the cliff are innate. Such an interpretation is supported, however, by the experiments with non-human infants. On our visual cliff, we have also observed the behavior of chicks, turtles, rats, lambs, pigs, and dogs—as well as the kittens and kids pictured here. These animals showed various reactions, each of which proved to be characteristic of their species. In each case, the reaction was plainly related to the role of vision in the survival of the species, and the various patterns of behavior indicate vision's role in evolution.

Kids and lambs can be tested on the visual cliff as soon as they can stand, and their response is predictable: no kid or lamb ever stepped onto the glass of the cliff side, even at one day of age. When one of these animals was put down upon the glass over the cliff, it displayed characteristic, stereotyped behavior: it would refuse to put its feet down and would back up into a posture of defense, its front legs rigid and its hind legs limp. If pushed forward across the glass until its head and field of vision crossed the edge of the surrounding solid surface, the animal would then relax and spring forward upon this surface.

At the Cornell Behavior Farm, a group of experimenters has carried these experiments with kids and goats a step further. They fixed the patterned material to a sheet of plywood and were thus able to adjust the "depth" of the deep side. With the pattern held immediately beneath the glass, the animal would move about the glass freely. With the optical floor dropped more than a foot below the glass, the animal would immediately freeze. Despite repeated experience of the tactual solidity of the glass, the animals never learned to function without optical support. Their sense of security or danger continued to depend upon the visual cues that give them their perception of depth.

Cats are nocturnal animals and, like rats, are sensitive to tactual cues from their whiskers. But whereas a rat is apt to rely primarily on its sense of smell and tactual cues the cat, as a predator, also relies strongly on its sight. Kittens proved to have excellent depth-discrimination. At four weeks—about the earliest age that a kitten can move about with any facility—they invariably chose the shallow side of the cliff. When put down on the glass over the deep

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Dr. Gibson, of Cornell University, and **Dr. Walk**, of George Washington University, collaborated on the depth perception experiments described here while at Cornell.

Kid relaxes noticeably as soon as its ield of vision has crossed edge of board.

Safe on the crossboard, kid peers over chasm. Action of even one-day-old kid is predictable: animal seldom steps onto glass over deep side of its own accord.

ide, they either froze or circled aimlessly backward until hey reached the solid assurance of the center board.

All our observations were in agreement with what is nown about the life history and ecological niche of each f the animals tested. The survival of a species requires hat its individuals develop discrimination of depth by the ime they take up independent locomotion, whether at one lay (the chick and the goat), three to four weeks (the rat nd the cat), or six to ten months (the human infant). That uch a vital capacity does not depend on learning by posibly fatal accidents in the lives of individuals is, of ourse, entirely consistent with evolutionary theory.

WE set out next to determine which of two visual cues plays the decisive role in depth perception; for to an ye above the center board, the optical pattern on the two ides differs in at least two important respects. On the *deep* ide, distance decreases the size and spacing of the pattern lements projected on the retina. "Motion parallax," on he other hand, causes the pattern elements on the *shallow* ide to move more rapidly across the field of vision when he animal moves its position on the board or moves its ead, just as nearby objects seen from a moving car appear o pass by more quickly than distant ones.

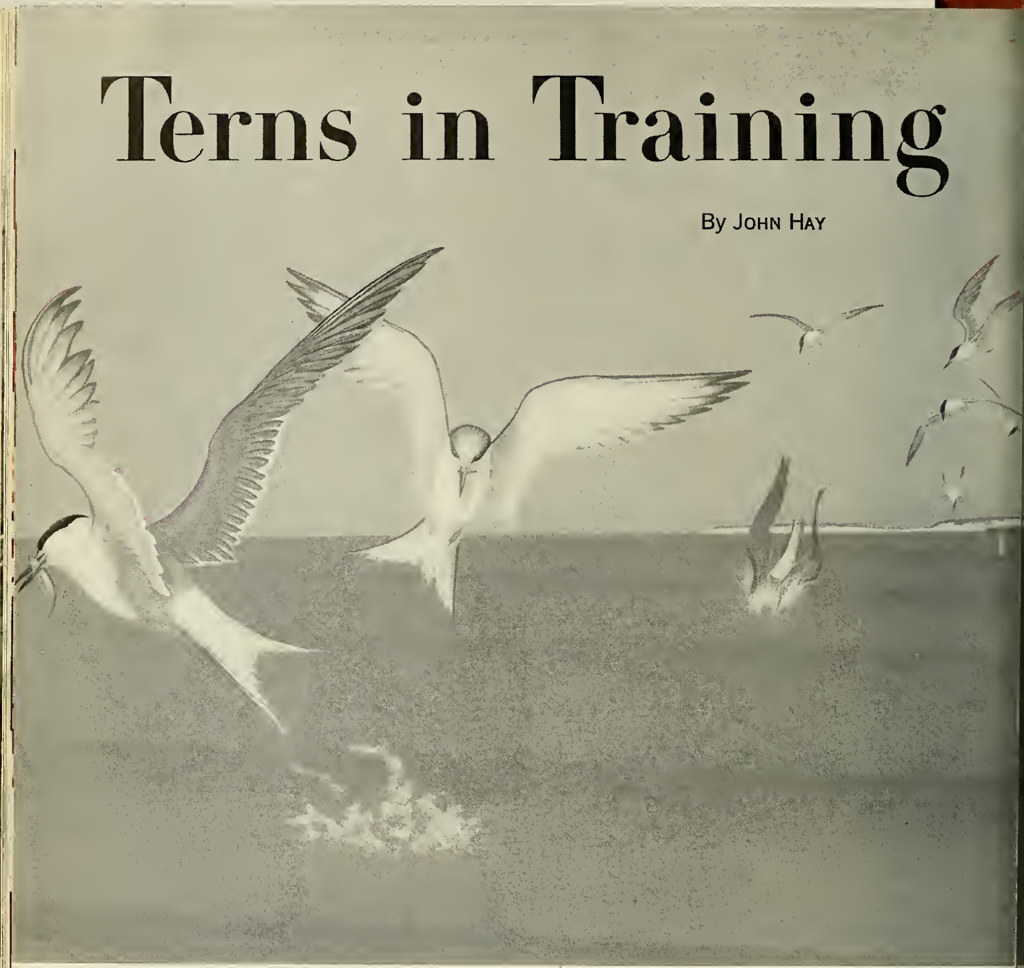
To eliminate the potential distance cue provided by patern density, we increased the size and spacing of the pattern elements on the deep side in proportion to its distance from the eye. With only the cue of motion parallax to guide them, adult rats still preferred the shallow side, though not so strongly as in the standard experiment. Infant rats chose the shallow side nearly 100 per cent of the time under both conditions, as did day-old chicks. Evidently, both species can discriminate depth by differential motion alone, with no aid from texture density and probably little help from other cues. The perception of distance by binocular parallax, which plays an important part in human behavior, would not seem to have a significant role, for example, in depth perception by chicks and rats.

To eliminate the cue of motion parallax, we placed the patterned material directly against the glass on either side of the board but used smaller and more densely spaced pattern-elements on the cliff side. Both young and adult rats preferred the side with the larger pattern, which evidently "signified" a nearer surface, but it may be that learning played a part in the choices shown by the rats.

From our first few years of work with the visual cliff, then, we are ready to venture the rather broad conclusion that a seeing animal will be able to discriminate depth by the time its locomotion is adequate, even when locomotion begins at birth. But many experiments remain to be done, especially on the role of different cues and on the effect on the animals of different kinds of early visual experience.

Terns in Training

By John Hay

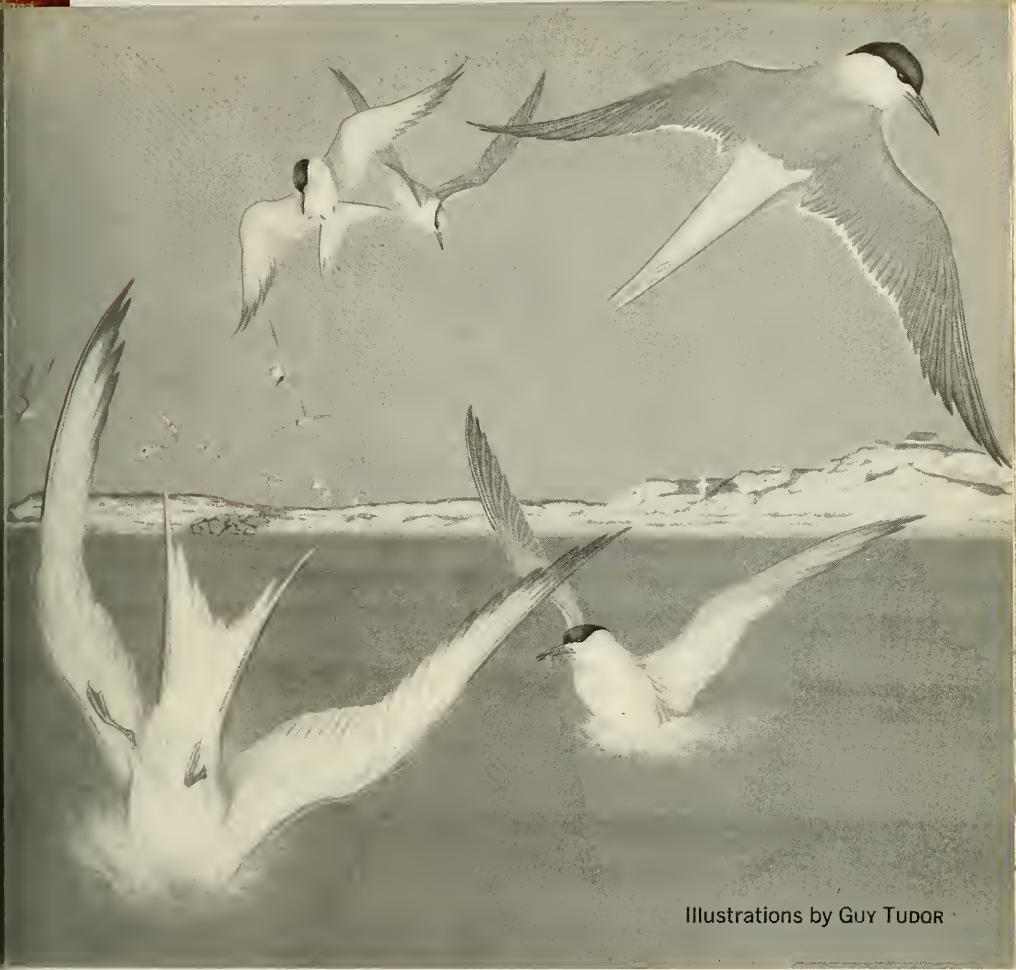


That elegantly formed bird, the tern, is not likely to have been overlooked by summer visitors to Cape Cod or to many other areas along our Atlantic coast line. As it hovers over the water and then dives for fish, a tern, with its sharp contours and arrow-like descents, is a pleasure to watch. These birds are an animate revelation of keenness and precision. They pinpoint the summer waters with flashes of spray, from which they rise with silver prey in their bills. They seldom miss in their quest for food.

Is there any action more full of grace than what some observers have called the "aerial glide" of a pair of terns? This spectacle may occur, among mated adult birds, at any time from the beginning of the breeding season until after the young are flying on their own. One August not long ago, I watched such a pair come in over the shore after they had been beating low along the wind-silvered waters of Cape Cod Bay. Suddenly, the pair mounted high up together, then raced in overhead. It was a sort of fast, lilting run. They came very close together, in synchronized proximity, like a pair of champion skaters. Then this lovely chase looped back and swung lower down, shifted on a slanting keel, and passed over the water once more.

Being a bird not only smaller but less in evidence than the omnipresent herring gull—which dwells on our shores, roosts on our houses, and scavenges in greatly increasing numbers at our town dumps—the tern seems a shimmering visitor, a bright surprise. Terns seem nervous and excitable by nature, and they are often unpredictable in their social movements. They are evidently sensitive to environmental change and to fluctuations in food supply: colonies have been known to desert nesting grounds in mid-season.

In the general area of Cape Cod there are two principal nesting places: Tern Island, at Chatham; and Plymouth, on Cape Cod Bay. During the season—the birds arrive about the end of April—both terneries have populations that number in the thousands. There are, in addition, a few small islands off the Cape and a few comparatively isolated areas where smaller aggregations often nest successfully, although terns are sociable birds and



Illustrations by Guy Tudor

reed best in large numbers. Begin-ing in August with the Arctic tern. hich is the earliest to migrate, the irds start to leave these nesting sites, ound south in groups or small com-anies. They spend the winter any-here from Florida southward al-nost to the edge of the Antarctic ice.

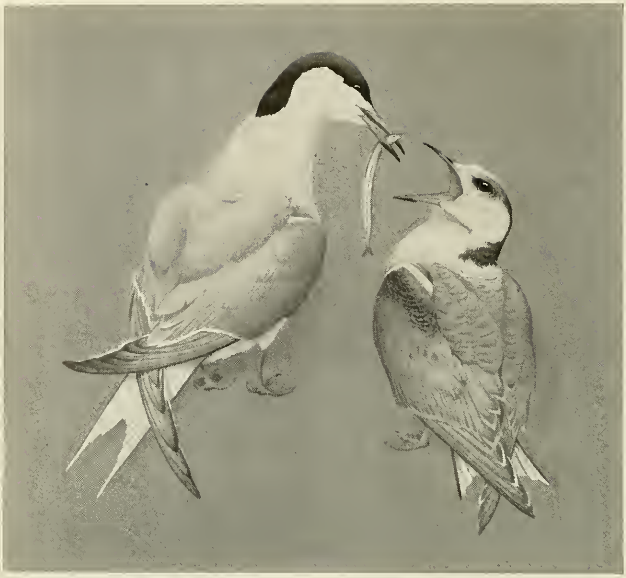
It was about the middle of August hen I first saw four or five hundred ommon terns appear in an area where had not been aware of them before. was high tide and the birds flocked long one bank of Paine's Creek, a dal estuary that flows out to Cape od Bay from the township of Brews-r. The stream, cutting through grass-ooted dunes, separated the terns from town beach and landing. During ebb des, at this time of the year, its brackish waters carry out large numbers of alewife fry, “inland herring” that have hatched in Brewster's fresh-water ponds. Since there is also an abundance of sand eels in the area, the terns had a good fishing ground.

From what nesting colony or colonies the birds had come was impossible to tell. In any case, Paine's Creek represented a way station on one leg of their migratory journey south, and the first such stop for birds that had hatched in late spring or early summer, as well as for the older birds.

MOST terns reach flying age within a month of birth, but their parents go on feeding them for some time, even at the outset of the southward migration. The young birds are slow to mature and do not breed until they are about three years old. I could see by their plumage and their behavior that many of the birds at Paine's Creek were immature. The crowns on the heads of the adults are jet black, while the heads of the young are gray.

Some of the young were making inexperienced flights over the water. They plunged in and sprang out of the water in an almost kittenish, hit-or-miss way, while the adults were hovering and diving with precision. Most of the immature birds, however, stood dependently along the beach or on shoals at the inlet's mouth, crying and begging their parents for food.

Terns are intensely active and brilliant in performance. Although comparatively small birds, they are made



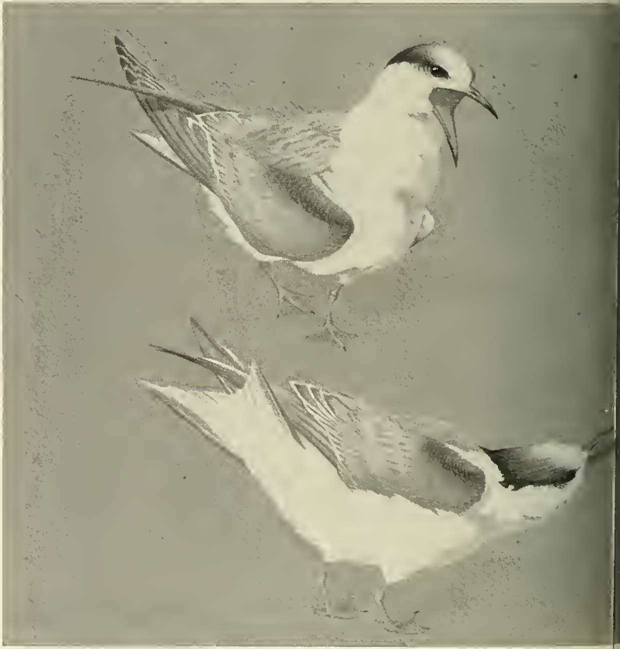
Large fish is being freely offered by a parent tern to its twittering, gaping young, *above*. Sometimes adult gives an entire fish; other times, only a part.

for journeys that take them thousands of miles, and their long, angled wings beat deep, low, and strong. I watched them, this shining August day, as they flashed with the brightness of gold circlets of water around sharp grasses along a shore. They were all swinging, darting, winnowing the air. "Kierr! Kierr!" they cried; and their white shuttlecocks of tails would spread and settle as they turned against the wind.

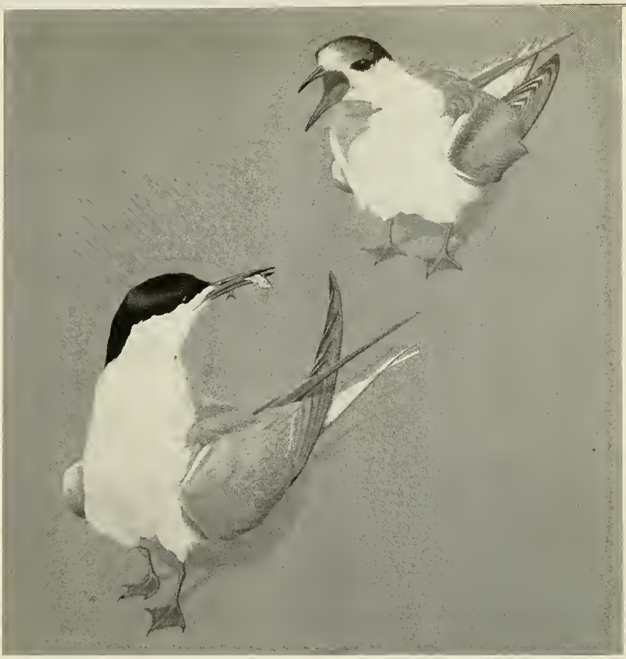
Two juveniles were waiting on a shoal, constantly calling in a high-pitched tremolo, intensified whenever the parent bird swept by above them. As I watched, the trim, expert adult flew over, then swung back down the shore and circled round, finally coming in to land between the pair. The adult had no food, but stood between its young for a minute or less and then began to move away, while they crouched and strutted after it in what, to human eyes, was an almost elderly way, crying in protest. The parent signaled departure with a slight lift of its wings and, in a few seconds, flew away. The thwarted young ones took to the air behind the parent.

In the terns' behavior that August day, I saw the play of learning, and the many repetitions that precede a balanced natural art. Other adults swung in with sand eels or alewives in their bills, and hovered, or circled back, avoiding rivals. Then they would drop down, next to a twittering, gape-beaked juvenile, sometimes giving it the whole fish, and sometimes holding on to half of it and flying away—an action that had the effect of teasing the young bird to follow after. In this way the young, some still crouched as if they were nestlings, became increasingly adept at flying up, chasing, diving, and dodging, at breasting the air, and beating their wings for all the long voyages their lives would hold. In a few weeks, most of these birds would suddenly flock away, in the next move of their migration. In the meantime, they practiced the lessons of growth—training in the insistent, excitable ways of a tern, a prelude to life in air over half the earth.

During the following weeks, on through September, I noticed that the plumage of the juvenile terns began to show a more definite contrast. Their heads were getting darker



Preparatory to flying off, parent tern moves away fro between its two young, *above*. Deprived of food and cryin

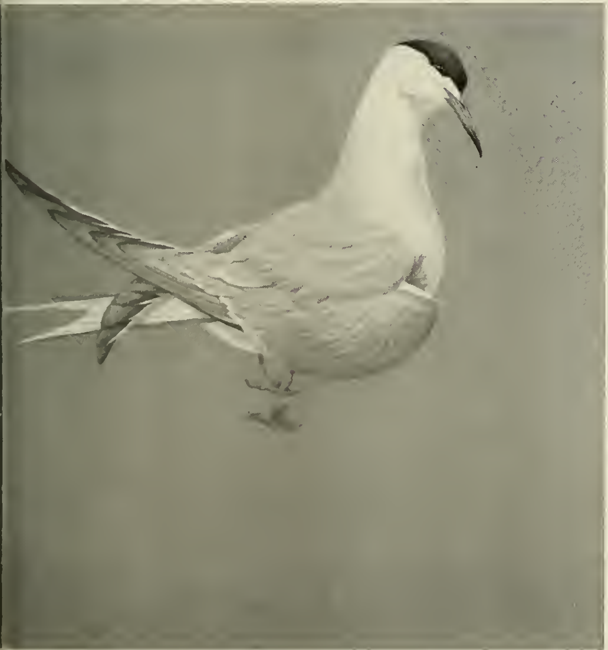


The adult tern, *above,* carrying a little fish in its beak, turns away from its fledgling. Offering and withholding of fish is basis of all training of young.

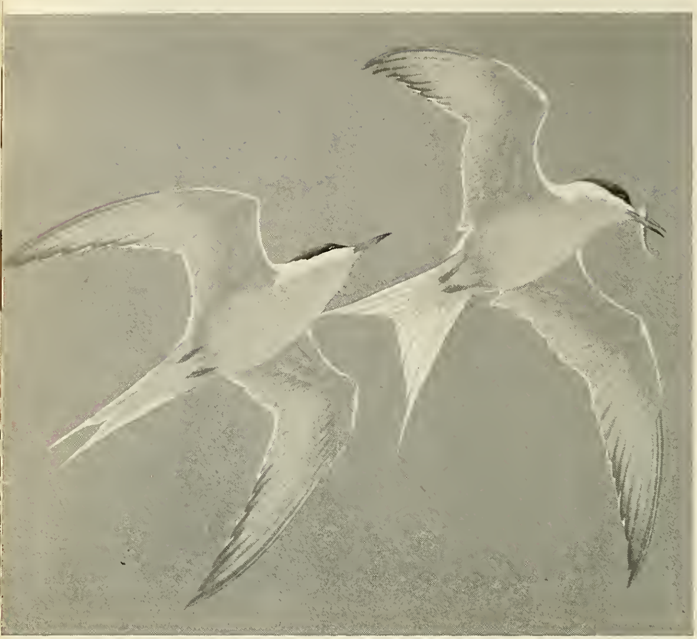
ey had also become more practiced flight. Many young were still being l by adults—almost continuously ring ebb-tide hours, when food was undant in shallow waters offshore. ot the impression that less food was ing proffered by the parent birds, ough they were still very much on job. When they brought a fish, ir large dependents, whose passiv- almost looked like a consequence being overly stuffed, would gulp it wn and wait for more. Other young es were flying now: chasing after ir parents, beseeching attention, t often fishing for themselves.

Little by little the young were pro- ssing toward the perfected action mature birds. They were becoming re aggressive, fighting for space er a crowded channel, or protecting ir catch. The adults, whose success fishing they were beginning to ap- oximate, would hover over the ter. beaks pointing down. then dive ldenly, wings partly folded back. ey would hit the water like small nes. then come up again and fly ay fast—chased, if they had a fish in their bills, by other birds that cried "Karr! Karr!" with a slightly growling note. I became aware of a general coordination in everything they did. Their circling, diving, hovering, or racing downwind, were all parts of a common proficiency of motion that fitted the great environment of air and sea. Growth was rhythmic practice.

Many aspects of tern behavior have been studied exhaustively by such authorities as Niko Tinbergen, Ralph Palmer, the late Oliver Austin, and his son, Oliver Austin, Jr. From their descriptions, I had accumulated the impression that terns were almost constantly involved in a ritualistic performance. There is, for example, the "fish flight," a term that in its strict sense seems to apply to the behavior of birds during the precourtship period. This action involves emotional display between pairs of birds, as distinct from a tern's food-collecting habits in general. In detail, it includes differences in calls, in the relative positions of birds during flight, and in the way they carry fish. A fish in the bill represents not only the fulfilment of a need for food; it may also be an offering, a display, and perhaps the instrument for a mutual awareness,

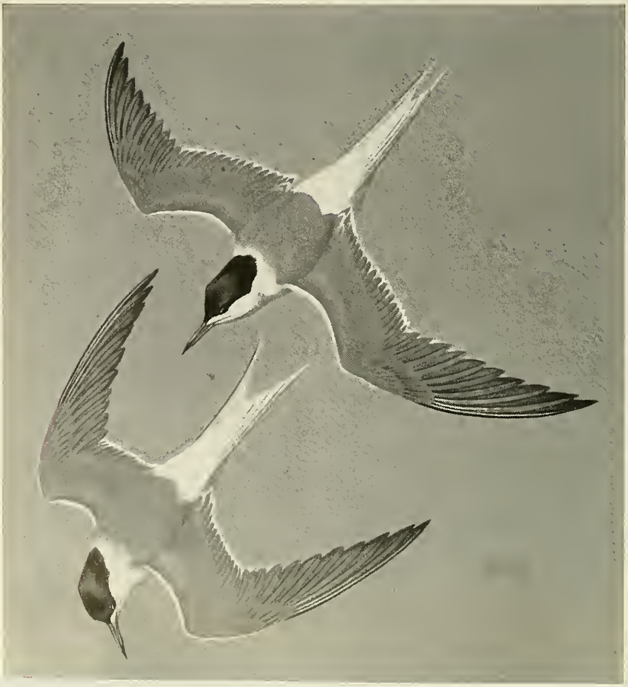


protest, they strut after their parent and will then fly er it: thus they are coaxed into fending for themselves.



IN A "FISH FLIGHT," *above*, an adult pair of terns seems more engaged in display behavior than in actual quest for food.

MATED ADULT TERNS are often seen in "aerial glides," *below*, during breeding season and until after young can fly.

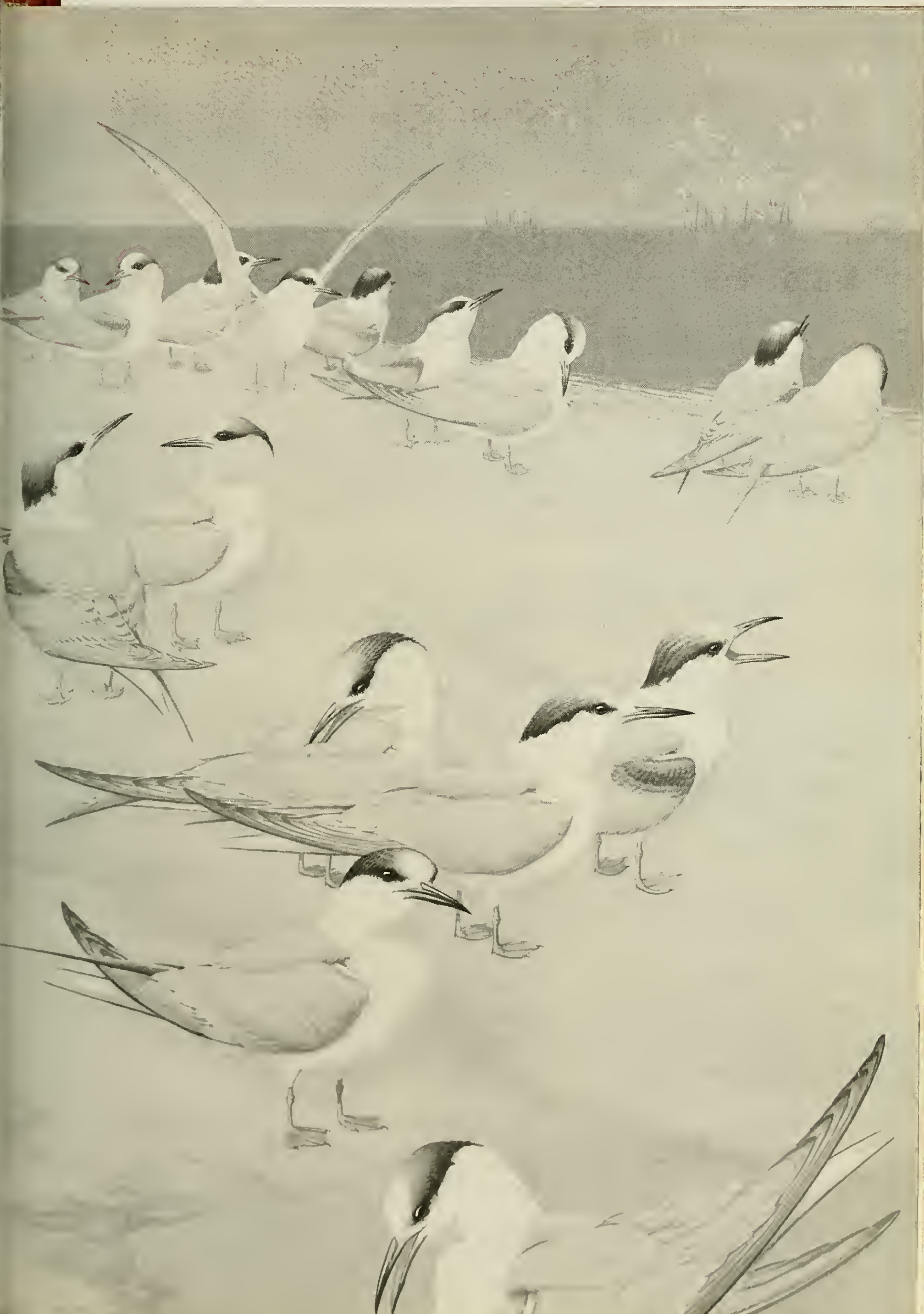


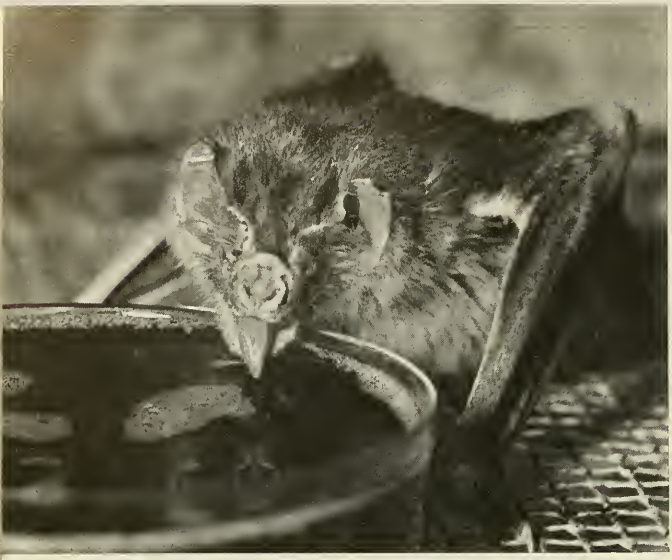
MR. HAY frequently contributes to this magazine. His article appeared in somewhat different form in his latest book, *Nature's Year*, which was published by Doubleday in May.

even before sex recognition occur But if this fish flight can be linke to behavior at a particular stage in tern's life, the birds also show simila reactions before and after that stag Palmer points out (in *A Behavio Study of the Common Tern*) that, a though no fish is involved during th aerial glide, this graceful maneuve still represents a continuation of th fish flight phase. Also, mated pai go on offering fish—or begging—a they fly by one another, so that fee ing is used, in Palmer's words, "as means of maintaining a bond." An of course the fish, proffered or wit held, is the basis of all the trainin that the young experience during tl course of growth. The process of be ging and receiving, or offering for th purpose of recognition, continues in many forms throughout a tern life. The birds appear to be pursue of a formality. Even their flights sho the grace in action of a whole societ

AT low tide, the terns I watch those months would begin flock along the wide sand flats, pree ing and bathing in the tide pools. O casionally one would lift its wings into the wind while it preened, recei ing the wash of air. Some flew to t creek inlet and drank of the bracki water. As the September days went b the whole tern community seemed gather more and more together. times, all of them would take to t air, as if in alarm, although no cau was visible. Or I would see them spi ning like a flock of sandpipers- white cloud dancing with dizzy p fection over some fishweirs in the d tance. Perhaps these actions could called communal practice for the ne step in the southward journey. In th rhythms, the terns were self-sustain and self-protective, like schools of fi But, at the same time, the birds we living under the laws of the wild a One day in early October, when I we down to the shore again, most of th had flown away. One lesson was ov

MIGRATING TERNS, including young well as mature, gather on coast, *rig* attracted there by offshore fishwei





Concave tongue of vampire fits over a V-shaped notch in lower lip. This forms tube through which animal sucks blood —in this case from dish in a laboratory.

THE MEXICAN BLOOD DRINKERS

Vampire bats display special adaptation

By Bernardo Villa

Among the many species and subspecies of bats known from the Americas, 140 are now known from Mexico. Among them are vampires, or blood-drinking bats, which have proved to be the main reservoirs and vectors of the fearsome rabies virus.

Vampires' biology and feeding habits have interested man since ancient times. For instance, the Cakchiquels, a Mayan tribe, believed the Camazotz—the vampire—was a god who killed victims with his sharp, pointed teeth.

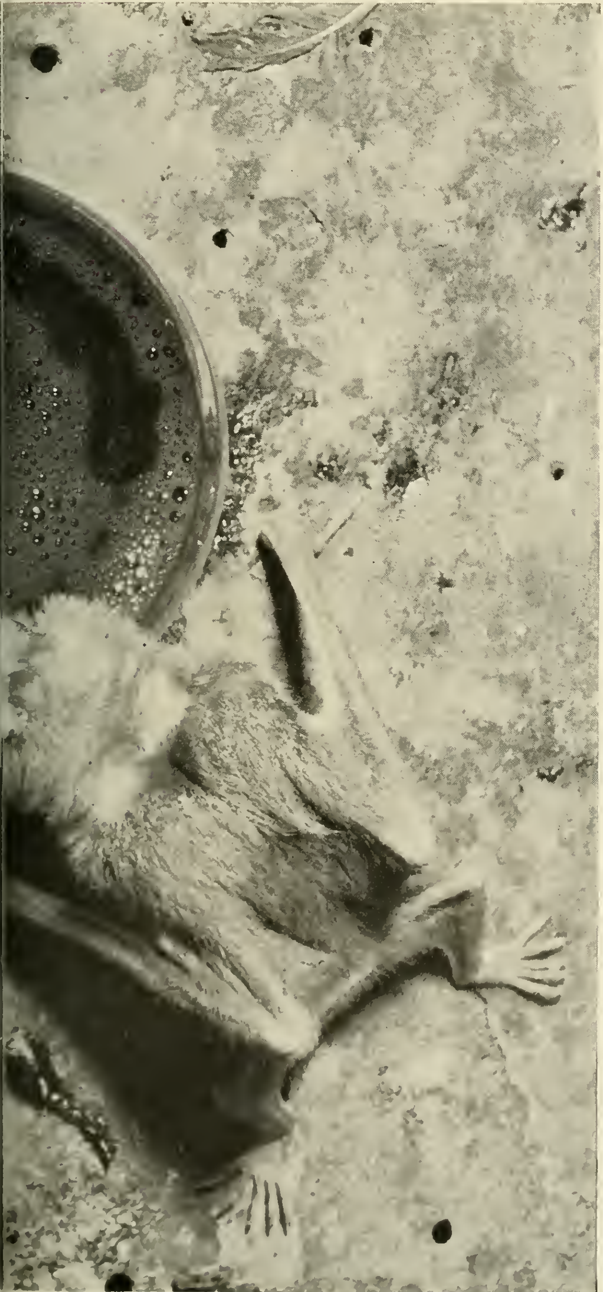
Recent observations in field and laboratory have shown that their bite may indeed be fatal, as it opens the way for rabies infection. But, contrary to the beliefs of naturalists of the eighteenth century, the wound is not made by the nasal leaf (which, in fact, is not found in vampires), nor do the bats fan their intended victims to sleep before allegedly thrusting the tongue into a blood vessel and drinking.

We now know that the mouth and tongue are specialized to imbibe blood in a manner without parallel among other mammals—or, indeed, among other vertebrates. The V-shaped notch in the lower lip is opposed to the concave lower side of the tongue. This forms a tube, through which the bat, after first making the wound with its sharp upper incisors, sucks blood. Thus, there is no lapping, the sound of which might awaken the victim. To further reduce any sensations on the part of its prey, the bat rests lightly on its wing thumbs and small foot pads.

The photographs showing this manner of feeding were taken in the zoology laboratory of the Instituto de Biología at the University of Mexico.

Dr. Villa, who took the photographs for his text, heads the Department of Mammalogy in the Institute of Biology at the University of Mexico.

While taking blood, vampire rests o
pads of feet and long wing thumbs, thu



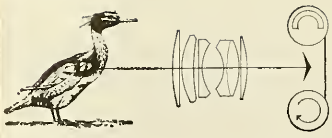
ucing surface contact with victim to imum. Bat above, genus *Desmodus*, is, like other vampires—and contrary to legend—confined to New World alone.

After drinking 20 or 25 cc. of blood, bat begins withdrawal to roosting place.

On wing thumbs and feet, a bat can cover ground with remarkable speed.

While backing up wall of its cage, bat pauses to assume typical defense pose.

Two vampires hang characteristically from roost in corner of laboratory cage.



NATURE and the CAMERA

Challenges of underwater photography

By David Linton

I was prowling peacefully along a rocky shore, collecting mussels for dinner, when I heard a splash. Just beyond the outer line of rocks I saw a column of water vapor shoot into the air like the spout of a whale, but in miniature. A glistening black object broke the surface. It floated for a minute and then, instead of diving, it started moving slowly toward shore. As it approached, I could see that it was about the size of a porpoise and had a bright, fluorescent yellow stripe along the water line. As it pulled itself up on the beach, the eyes came into sight. They were about four inches in diameter and were located on the ventral surface, one behind the other! The creature got up on its hind flippers and waddled awkwardly toward me. It was my friend, Martin, in his new skin-diving suit. The upper eye was his face mask, the lower one was the port of a camera housing strapped to his chest.

"I got some wonderful pictures," said Martin, ". . . if they come out."

How that phrase took me back in memory! It had been years since I'd wondered whether a picture would "come out." But when I started taking underwater pictures myself, I found that no thought could be more appropriate.

Underwater photography was much in vogue about five years ago. Photographers, apparently suffering a mass attack of Cousteau's "rapture of the deep," trooped down to the sea like lemmings. Everything was photographed under water—telephones, automobiles, models in drip-dry suits, pretty girls in bathing suits, pretty girls without bathing suits, housewives pretending to make toast, and children pretending to drink soda pop. Most of these pictures were not remarkably good, but it *was* remarkable that they could be taken at all. They attracted attention, and that was what they were supposed to do. By now everyone has seen pictures made under water, the hucksters have moved on to other gimmicks, and underwater photographers can return to photographing things that really belong to the undersea world.

Stepping into the sea with mask or goggles is much like entering the world behind the looking glass. The silvery barrier that seems so thin and yet so formidable opens only enough to let one pass, and closes immediately. The undersea world is breathtaking, and before long you want to take pictures of it. Then comes the rude discovery that entering that strange, submarine world means retrogressing to the dawn of photography.

We have got used to the fact that, in air, the camera can photograph anything the eye can see—and often more. It can cut through fog, it can look a fly in the eye, and it can bring distant subjects closer. Almost anything you want the camera to do can be done—if you have the money for accessories. Almost any technical information you may want is published in handbooks.

In that other world below the surface, everything is different. The experts still hand-build much of their own equipment. (When did you last build a camera?) There are no reliable tables of exposure, filter factors, development times, or any of the other things we have come to take for granted. The few tables that *have* been published hold good only for the waters where they were derived, and the only sound recommendation is to make a test and see if it comes out. If it does, you still won't know much, because underwater optical conditions change from day to day, and even from hour to hour. And, under water, the camera can see much *less* than the eye. This is partly because we have two eyes and can therefore concentrate on things at one particular distance, ignoring what is in front of and behind that point. But a larger factor is the marvelous ability of the mind to perceive shapes and organize visual clues. The eye can detect minute differences in color or texture. The perception of motion helps, too. Many forms of marine life are so camouflaged as to be invisible until they move. Needless to say, they are completely invisible in a still photograph. The only way to photograph them is against a different background—one that they don't match. A ray lying on the bottom is virtually impossible to see in a photograph, but a ray swimming can be seen from the side against a background of water, or from below against the surface.

When we pick up rocks or sea shells at the shore and take them home, they seem somehow to lose their luster. The same is true of the wonders we try to capture on film. I am afraid the truth is that just as the eye can see under water only a fraction of what it can see on land, so the camera under water can record no more than a fraction of what the eye can see. Water clear enough for good undersea photography is found in only a few places, and then only at certain times.

The water is very clear in the Bahamas and there are enormous stretches of white sandy bottom at twenty feet or less that reflect light and give a beautifully rounded illumination. Marine life there, however, is not as abundant as in waters that offer more food and more concealment. When the movie *20,000 Leagues Under the Sea* was filmed there, whole undersea gardens were brought in and set up by prop men. Even so, the film company sat for several weeks waiting for good weather.

In the Florida Keys there is more to photograph and the water can be very clear at times. May and June are the best months. But coral shores undergo a continual "snowfall" of minute particles of eroded coral. The slightest wind stirs up the bottom enough to prohibit picture taking, and a severe storm will cover the underseas landscape with two or three inches of silt. One day in five may be a good day for underwater photography.

The best conditions are found in the eastern Mediterranean, where the water is as clear as laboratory distilled water, and in certain large springs where the water is free of organic or mineral sediment. (Many of the "gimmick" pictures of the early underwater period were taken in these springs.) They generally do not support much aquatic life. Other waters vary from fair to impossible.

Have you ever wondered why we do not see any over-all pictures of the sunken Spanish galleons that writers are so fond of describing? The answer, I suspect, is that no camera can see from one end of such a ship to the other. It may almost be taken as a fundamental law that "there are no long shots under water."

These discouraging facts are forced on us by the nature of the medium. Water is much less transparent than air, and natural bodies of water (as distinct from swimming pools or aquariums, where the water is filtered) contain quantities of minute particles in suspension. Some of these are plants, some are animals, and some are bits of sand, mud, or coral, but they all impede the passage of light. Some of the particles absorb light (actually they convert its energy into heat) and others reflect or "scatter" it. Scattering is more of a problem for the photographer than absorption. It produces the same effect that heavy dust clouds or thick fogs do in the air. There

Calm, shallow water permits a clear photograph of an octopus near the shore.

ay be plenty of light and still it may be mpossible to see more than a few feet.

Because of the difficulty of recording ny distant background and because the hotographer must work as close to the ubject as possible, most underwater pic- res appear flat. They are not only flat the photographic sense—the images ck contrast between light and dark nes—but also are flat in the sense that ey fail to appear three-dimensional.

To overcome photographic flatness, a irly energetic developer should be used r black and white films. I have had best sults with UFG. Developing times ould be 10 to 20 per cent longer than sual. Although it seems a good idea to se a slow film because such films have igher inherent contrast than fast ones, is probably better, in actual practice, use a medium-fast film in shallow ater and a fast film in deep water, so at the lens aperture can be kept small overcome difficulties in focusing.

It is not really practicable to increase ntrast in color, but fortunately this is t usually necessary. Kodachrome is a ther contrasty film, but it is not a good oice under water because it empha- zes blue and green, which need to be duced. Ektachrome (particularly the w High Speed emulsion) and Ansco- rome will give better color rendering, d their higher speed will allow use of smaller aperture. Kodachrome II is so w that I have not yet evaluated its un- rwater performance.

There are other tricks for overcoming e other kind of flatness—lack of ap- rent depth—although, of course, these icks do not really restore what low vis- ility takes away. Framing is the most ective technique. This means having a rk object in the near foreground at the ge of the picture. Shooting through a le in a coral or between two rocks is a od way to achieve this effect. The best y is to shoot from inside an under- ter cave, but since caves are often quented by moray eels and other unfriendly creatures, I would hesitate to advise any readers to back into them.

Another useful technique for simulating depth is back-lighting. This means simply having the light come from behind the subject. It is frequently impossible, of course, but it is usually worth trying. Shooting up at an angle toward the surface is one way; photographing fish in the shadow of your boat is another. Framing and back-lighting are useful above water, too, especially when the air is dusty or foggy. They have been used in many of the best pictures of rodeos, marine mists, and London streets.

INCREASED exposure will not help penetrate underwater murk because the film will record the scattered light instead of the image we want to see. In fact, a minimal exposure and extended development are best. Filters will improve the situation a bit. The suspended particles scatter more blue and green than other colors, so a yellow or orange filter will reduce the intensity of the scattered light somewhat and will allow more of the image to show. But no filter will eliminate the particles themselves.

When shooting in color, filters can be used only sparingly—just enough to restore the balance of the different colors that make up "white" light. The filters used for color, therefore, will not help much in penetrating underwater haze. (Exactly the same limitations apply to aerial photography through fog; the heavy filters that give maximum penetration in black and white cannot be used for color because they would eliminate most of the color from the picture.) Color does help, however, by making the subject stand out and by increasing the feeling of depth. For this reason color pictures are often better than black and white photographs of the same subjects, but the shooting conditions must be better for color to succeed at all.

Only if the water appears *exceptionally* clear to the eye will it seem less

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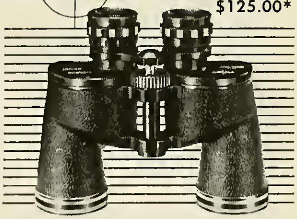

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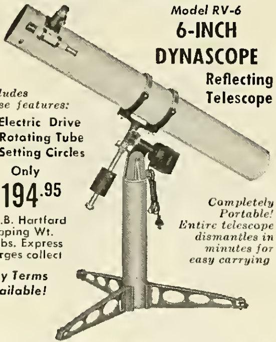

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than opaque to the camera and, even then. the best technique is to move in as close to the subject as possible in order to minimize the number of particles between it and the camera.

The amount of solid matter suspended in the water varies with time and place. The problem of refraction, however, is the same in all waters. Refraction is the phenomenon that accounts for the apparent "bending" at the water line of a stick thrust into water. It makes everything under the water appear one-third larger and closer than on the surface. This effect fools the camera as well as the eye. A fish that appears to be three feet away will be photographed in focus if the camera is focused at three feet, but the actual measured distance will be four feet. The scattering and absorption of light, however, is determined by the full four feet of water between camera and subject. The definition and contrast of the image decrease rapidly as the actual distance increases, so the clearest pictures call for a short actual working distance and even shorter apparent range. Here is where trouble usually starts.

MANY common types of cameras have a minimum focusing distance of three feet in air. Under water, this visual distance of three feet means an actual, measured distance of four feet, which is frequently too far for a satisfactory picture. Furthermore, the depth of focus and size of the field will correspond to the apparent distance of three feet, not the actual distance. It may be necessary to back up to include the whole subject, and that will decrease the visibility.

Another way of expressing this is to say that the lens acts as though its focal length were increased by one-third. The usual lens for a 35mm. camera has a focal length of 50mm. in air; under water its *effective* focal length is 67mm. and its depth of field and angle of view are those of a 67mm. lens. This is a bit long, but not impossibly so.

It is difficult to focus accurately under water, especially since the photographer and subject may be drifting in currents. A small aperture is necessary to obtain depth of field. A short lens has greater depth of field at any given aperture and is therefore preferable. This means, in turn, that the 35mm. camera is the most useful type of camera for underwater photography. It has a short lens to begin with, and on the better ones an even shorter (wide-angle) lens can be substituted for the "normal" lens. If the camera design permits, a lens of 25 to 35mm. focal length is desirable underwater.

I am not seriously considering cameras smaller than 35mm. in film size for underwater work. Although such cameras have very short lenses they cannot be operated practicably under water because of the tiny controls. If the reader doesn't believe this, let him try using one whil wearing gloves. Another, overwhelmingl persuasive reason for choosing a 35mm camera is the number of pictures it wil take before reloading. Remember tha in order to change film one will first hav to surface, then take off his mask an breathing apparatus, dry his hands an camera housing, remove anywhere fron one to fifteen bolts, and finally extrac the camera *before* he starts the norma reloading routine. The directions tha come with film say "always reload i subdued light; never in bright sun light." This is good advice, but hard t follow in a pitching rowboat anchore offshore. The ordinary load for 35mm cameras is a 20- or 36-exposure ca tridge. Many of the better 35mm. can eras have accessory backs that accep 50-foot rolls of film and allow severa hundred exposures before reloading.

UNDERWATER housings come in a va riety of futuristic shapes and mat rials. They look fancy, but compare with modern cameras, they are crud The Rolleimarin housing for the Rolle flex—designed by Hans Hass, an expe diver—is one of the few that can reall be operated conveniently under wate

GLASS-BOTTOMED BOX is used as came housing when photographing near surfa

and it is perhaps the only housing wi which a diver wearing a mask actua can see what he is getting on film. It h three main disadvantages. The Rol lens is too long; the camera will ta only twelve frames, after which the a paratus must be brought to the surfa and the case opened to reload; and t greatest drawback for many people the price of $400—without the camera

In the "under $400" class, an exp sive housing is not necessarily bet than an inexpensive one. The cheap type of all (selling for less than $10).

DAVID LINTON's by-line has appeared under photographs in all the nation's leading magazines. His camera column is a regular feature on these pages.

soft, plastic bag with a circular glass ort at one end. All the controls on the amera can be operated through the plas- c while submerged, an advantage that annot be claimed by many housings cost- ig well over $100. The heavier, cast- etal housings are watertight to greater epths, but this is a dubious advantage ecause there is not enough light to take ictures at those depths anyway, unless tificial light is used. A housing that is atertight to 250 feet and has no flash onnections is a waste of money. With any of these housings, the shutter peed and aperture can be changed only y opening the housing. This means that e photographer has to make a prelim- ary descent to take a meter reading—sealed fruit jar makes a good meter using—then surface to set the camera, en dive again to take the picture.

Even less convenient, most housings lling for $300 or less have no mechan- m for focusing the camera and no way seeing when it is in focus. They thus ansform an expensive camera into the uivalent of a box camera. True, the ns is faster, but if it can't be focused, has to be stopped down for greater pth of field, so the lens speed is wasted. is more sensible to buy a box camera. There is an underwater box camera lling for $15. It is made entirely of astic and the camera forms its own using. The shutter speed, focus, and erture are fixed, but the sensitivity n be controlled to some extent by ing different types of film. This camera ll do almost everything that an expen- e one will do and it has one great ad- ntage—if the case leaks, nothing will ruined but one roll of film.

A NOTHER radical, but highly practical, suggestion is not to take the camera der water at all but to shoot instead ough something like a glass-bottomed cket. A sophisticated version of this rsatile instrument can be built with a tangular glass bottom the same shape the negative. A mount can be installed hold the camera in a position such t its field of view corresponds exactly the window, and the whole box can be ned as a unit. Any ordinary range der or reflex viewing system can be d for focusing. Since the air in the x makes it very buoyant, it will be d to control unless weights are at- hed around the bottom. A focusing th or hood is usually necessary to pre- t reflection of the sky on the window. sers of reflex cameras might try a iation of such a box with the window the side instead of in the bottom. The nera placed on the bottom is pointed

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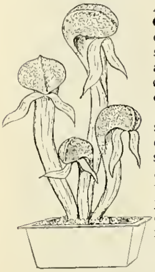

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out through the window. The photographer looks down into the ground glass screen. The box must be big enough so that the operator can reach down into it and work the camera's controls.

Of course, these boxes and buckets can be used only to photograph objects that are near the surface, but most good picture possibilities occur in this zone, anyway. The light falls off rapidly as we go down, and the color of the light changes, growing more and more blue-green. As I have mentioned, these effects vary greatly from one time and place to another, so it is impossible to make up any useful tables. But the very marine life we are interested in photographing depends on sunlight, too, and most of it is to be found in shallow water.

BELOW about twenty feet—the exact depth varies with the clarity of the water—natural light becomes too faint to use and the photographer must depend on flash or speed light. These sources work nicely under the water if enclosed in suitable housings, but the pictures taken with them usually exhibit all the disadvantages of terrestrial flash pictures, much magnified. The foreground is unnaturally bright, while the background is dark; textures are subdued where they should be brought out; and the shadows are in all the wrong places.

The best solution is to keep the flash away from the camera. Some flash units have telescoping arms that can be extended, but they are difficult to maneuver and even harder to swim with. It is often helpful to have a second diver hold the flash, although directing him is a problem, for one has to rely on hand signals. Since no one should ever dive alone, anyway, the photographer migh as well put his companion to work.

Despite its many difficulties, underwater photography can be an excitin experience, and the results can be impressive, as the many published examples prove. The best underwater picture become truly miraculous when one considers the obstacles that were overcom to make them. Most experts, if the really let their hair down, would agre that the "secrets" of successful underwater photography are:

1. Work in shallow water. In many o the best photographs, the surface of th sea is just out of the frame.

2. Shoot only at close distances. Th long shot probably won't come out.

3. Take plenty of time. Practice usin your equipment in a swimming pool c at the beach before you go farther out.

4. Try to shoot at the best time Make careful tests and have them deve oped as you work. Finally, don't expec more than one good picture a day. Bu that one picture can be worth it.

This list details the photographer, artis or other source of illustrations, by pag

COVER—Alexander Klots
4—AMNH
8-9—H. B. Whittington
10—The Smithsonian Institution
11—H. B. Whittington, top; Leif Størmer, bot.
12-14—H. B. Whittington; except 14—bot. AMNH Archives
15—H. B. Whittington, top; AMNH after Seilacher, bot.
16—AMNH after C. J. Stubblefield, top; H. B. Whittington, bot.
17—H. B. Whittington
18-19—Gene Wolfsheim
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22-25—AMNH after Pringle
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28-29—AMNH after Pringle
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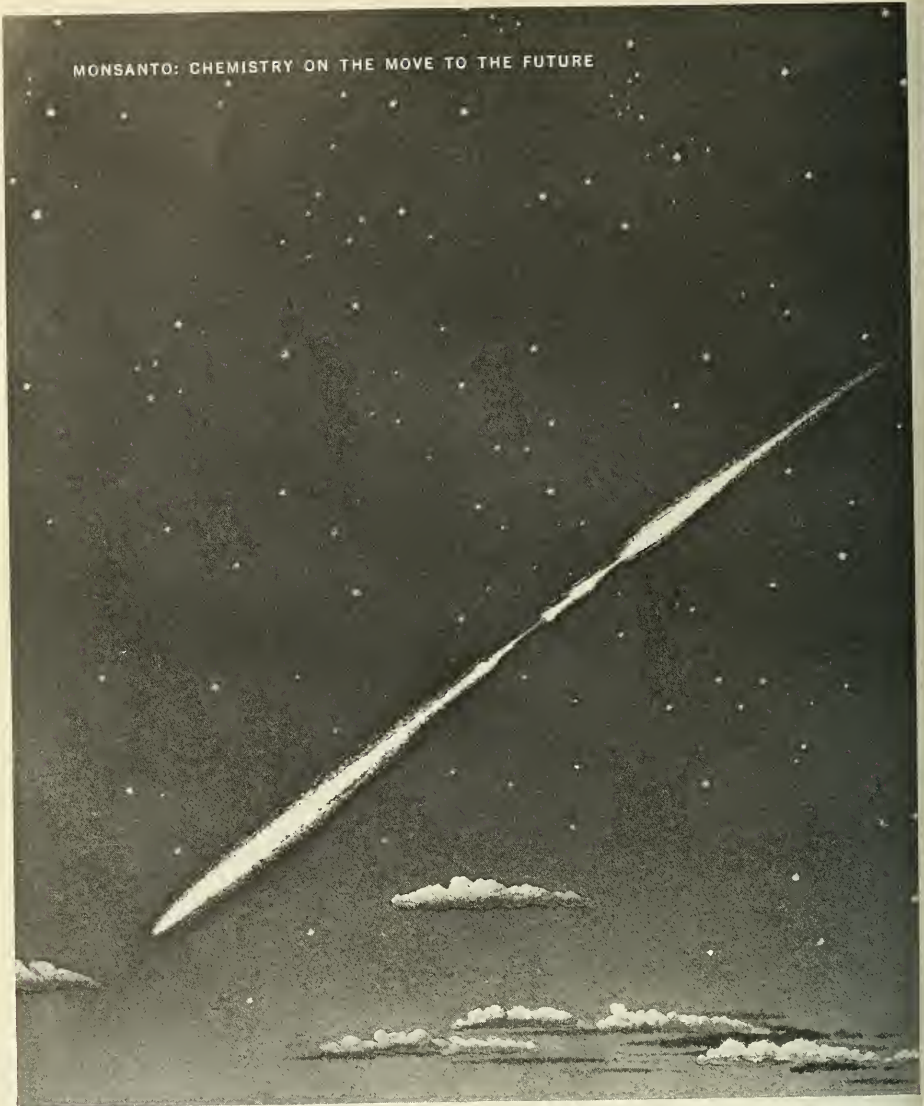
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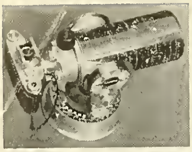

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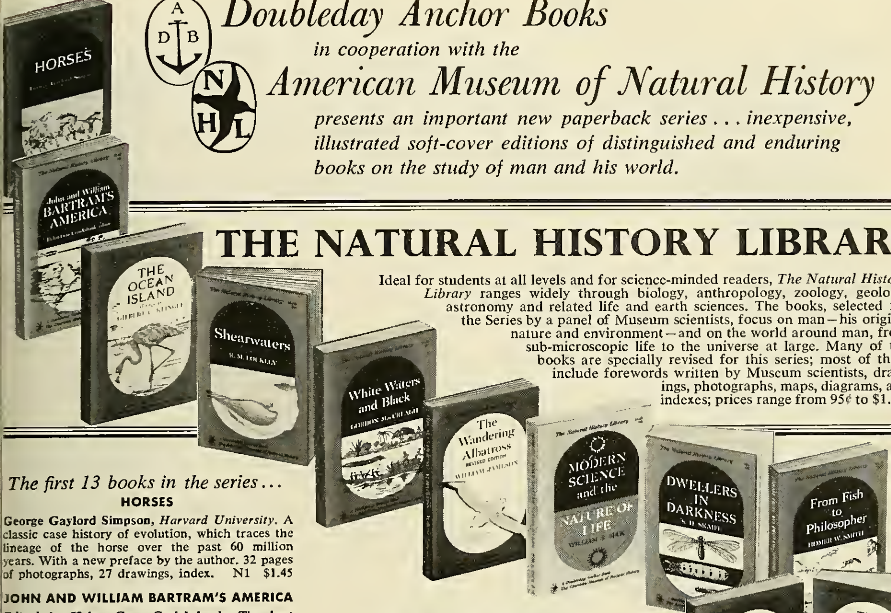

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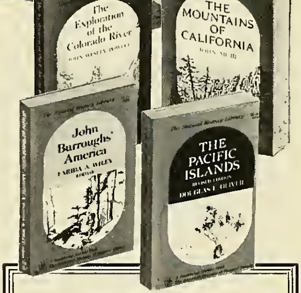
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DEPARTMENTS

MUSEUM MEMO
REVIEWS *Christopher Gerould*
SKY REPORTER *Simone Daro Gossner*
SPIDERS AND WEBS *E. Laurence Palmer*
YOUNG SCIENTIST *William M. Adkins III*

COVER: The jagged mountains of Baltistan, a remote region of High Asia, lo above Balti boatmen poling a skin raft across a river. This photograph was ma by James Hurley during one of his five visits to the country. Sometimes cal Little Tibet, Baltistan is inhabited by a people remarkable for its admixt of Caucasoid and Mongoloid racial traits and for its language, which belongs the Tibeto-Burman family but is written in Arabic letters. Although the B of today are all Moslems, previous religions have included totemism. Bon. Buddhism. Mr. Hurley's study of Baltistan and its population starts on page

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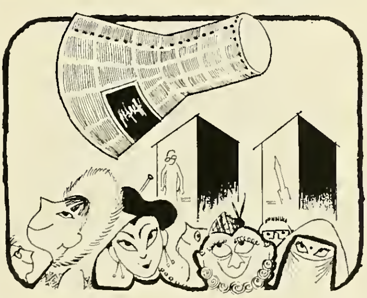
MUSEUM MEMO

AMONG THE 2,600,000 VISITORS to the Museum and Planetarium last year were heads of state and heads of households; tourists from Bangkok and teachers from Brooklyn; children standing for the first time at the gateway to science; parents sharing the joy of discovery; and grandparents renewing their early experiences.

On a Sunday afternoon last fall Crown Prince Akihito of Japan, guest of honor at the new Japanese exhibit in the Hall of Birds of the World, saw an exact replica of an area to the north of Mount Fuji in an exhibit that includes thirty different species of birds. Not long afterward Prime Minister Nehru paid a visit to the Planetarium and was shown the autumn skies over India reproduced on the dome. Another recent visitor, the Supreme Patriarch of Thailand, expressed keen interest in all the exhibits he viewed, from dinosaur footprints to lunar landscapes.

During the coming months Museum visitors from near and far will see new exhibits that range in subject matter from "Art and Life in Old Peru" to "Man in Space." The Peruvian exhibit contains rare treasures culled from private collectors and museums in Peru and the United States, many of which have never before been displayed. Our own collection will yield a good deal of this material, including examples, never before shown, of the oldest patterned textiles from the New World. These are fabrics excavated by Dr. Junius Bird of the Museum from the Huaca Prieta mound in Peru. Through his microscopic analysis Dr. Bird has demonstrated that fabrics are the oldest known medium of artistic expression in Peru.



It is a long step from life in ancient Peru to life in a space ship, but a Museum visitor will be able to make the transition very quickly.

The exhibit "Man in Space" will have as its main feature a full-size model of a five-man space laboratory, known as ARIES (Authentic Reproduction of an Independent Earth Satellite). The cylindrical model is forty-one feet long and fifteen feet in diameter. Revealed through its transparent shell will be the major part of the life-support system needed to keep a five-man team aloft for 60 days, while hey conduct experiments on a variety of biomedical problems that man will encounter as he probes space, looking for new frontiers of basic knowledge about the universe.

Through such exhibits, a Museum visit becomes a memorable personal experience. But this institution's role in teaching natural history extends beyond its halls. Across the country, people of many backgrounds are served by the Museum through a score of extension services and communications media. Most recent of these is *The Natural History Library*, published in co-operation with Doubleday and Company. This distinguished series of reprints of natural history classics, selected by Museum scientists, is attractively presented in colorful paperback format, thus making available to a wide public books of enduring interest in the life and earth sciences.

To encourage a sense of discovery in all who come within its sphere is a basic aim of the Museum. A favorite Museum headline, therefore, was a recent one involving three New Jersey teen-agers who were exploring an abandoned quarry and uncovered what turned out to be the fossil remains of a gliding reptile older than any previously known to science. The young men, who had been pursuing their fossil-hunting hobby under the aegis of Dr. Edwin H. Colbert of the Museum, recognized immediately that their find was a significant one. With infinite care they cut the rock to portable size, embedded the specimen in plaster, and brought it to the Museum. Here, a skilled technician, using a device resembling a miniature sandblasting machine, spent three months at the task of cleaning the fossil and exposing the delicate skeleton. After an exhibit arranged to give the public a chance to see the fossil, Dr. Colbert began an intensive study of it. His work on the 175,000,000-year-old fossil will be published in our scientific series and should shed light on a whole new facet of vertebrate evolution.

THE discovery itself was of paramount importance, but equally so were the circumstances, which seemed to us so clearly representative of the Museum's purpose. Three young boys, whose curiosity had been aroused and whose interest in science had been heightened so that they knew enough to value what they found, came upon a rare scientific treasure. Because of their quest, many other youngsters will come to respect the lessons of the past as well as look forward to the promise of the future.

ALEXANDER M. WHITE
President

Reviews

More solid reading between soft cover

By CHRISTOPHER GEROUL

THE FLOWING RIVER of "serious" paperback books, which was already a healthy stream a year ago, has now completely overflowed its banks. All major publishers seem presently to be involved in the paperback business, as are many specialized firms, notably the university presses. The reading public, superficially at least, has never had it so good.

Unfortunately the paperback output is subject to the law of diminishing returns as well as to the law of supply and demand. The reservoir of titles worth reprinting is not boundless and, as a result, there is an increasing number of paperbacks of questionable value—outdated textbooks and popularizations, as well as works of quite limited interest.

Basically, of course, these problems concern the publisher and the unhappy bookseller who must find room to display the exponentially increasing output. But there are serious corollary problems for the reader as well, including the critic as a specialized reader. The most obvious problem is simply how to find one's way round. In the first place, what has been published? For a quarter, the reader can get part of the answer from the subject index edition of *Paperbound Books in Print* (R.R. Bowker Co.), which is available in most stores specializing in paperbacks. The Bowker catalogue lists some 11,000 titles and is issued several times a year. Obviously it can never be entirely up to date, since publishers' plans change, but it is the best source for what is available.

Another quarter, mailed to the American Association for the Advancement of Science at 1515 Massachusetts Avenue, N.W., Washington 5, D.C., will bring a copy of *An Inexpensive Science Library*, prepared by the AAAS and The National Science Foundation. This annotated bibliography lists some 500 titles in 29 fields, and the current (fourth) edition is complete through July 1, 1960. To our knowledge, this is the only descriptive source available with listings in the biological sciences—although its notes are very brief. Beyond these two aids, the reader is reduced to finding his own way through the jungle. The review that follows is a necessarily limited attempt to note some of the more recent and more interesting additions to the paperback library since the last summary published here (NATURAL HISTORY, June-July, 1959).

A USEFUL sourcebook on classical astronomy, ending with the nineteenth century, is Arthur Berry's *A Short History of Astronomy* (Dover, $2.00). A hardy perennial among textbooks, it has the positive merit of treating the work of men like Kepler and Newton at length and the defect of a rather prosy style.

Another Dover publication in the field of astronomy is interesting on two counts. *An Elementary Survey of Celestial Mechanics*, by Y. Ryabov (Dover, $1.25), is a crystal-clear exposition of the basics in a field that is much less esoteric than it was a few years ago. The mathematics do not go above high school level, and the text includes worked-out computations of the orbits of artificial satellites—using the early Sputniks as cases in point. Even lacking an interest in the subject, the thoughtful American reader might spend an hour or two pondering the differences between this interesting but no-nonsense Soviet presentation and some of the angel food cakes that pass for popularizations here.

The popularizations of George Gamow are far above the pastry-cook standard, since the author is a physicist of repute as well as an accomplished and witty writer. At the same time, his *One, Two, Three . . . Infinity* (New American Library, 50¢) tends to another kind of superficiality by attempting too much in too short a space. The reader who follows Professor Gamow through a jet-propelled tour of modern mathematics, cosmology, nuclear physics, microbiology, genetics, and other fields, risks either an unwarranted feeling that he knows all about everything or the sens tion of a plain case of indigestion.

ONE of the better paperback scien ventures is the "Ann Arbor Scien Library" series, published by the U versity of Michigan Press. All are wr ten by European authorities, are we made physically, and are well ill trated. *The Sun*, by Karl Kiepenheu and *Planet Earth*, by Karl Stum (Michigan, each $1.95), typify t series. Stumpff's book is particula interesting to the biologically mind reader in its terse but detailed acco of the environment in which we live.

Still in the general field of astronom one of the classics of popular scien *The Universe Around Us*, by Sir Jam Jeans (Cambridge, $1.95), is now ava able in soft covers. It remains the b account of modern astronomy availa anywhere. Modern theories of the cr tion of the universe, as well as su topics as the earth's radiation be only recently mapped, are treated *The Universe at Large*, by Herma Bondi (Doubleday, 95¢). The book somewhat smaller than its title, both scope and accomplishment, being a co pilation of magazine articles by British astronomer.

Bondi's book is a volume in the "S ence Study Series," produced un eminent sponsorship with the purpose making up-to-date and authorita texts in modern science available secondary school students and the g eral public. One of the best of the ser is *The Restless Atom*, by Alfred Ron (Doubleday, 95¢), a history of the 65 years of progress in nuclear scien In this case the historical appro lends extra clarity in a field that is ways somewhat difficult for laymen

Another approach used in this ser is the biographical. *Pasteur and Mod Science*, by René Dubos, and *Michel and The Speed of Light*, by Bern Jaffe (Doubleday, each 95¢), offer

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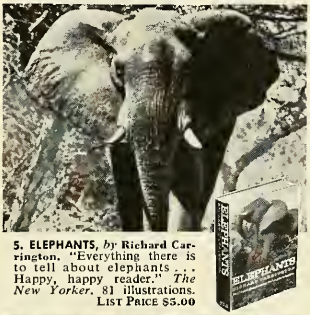

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interesting contrast of the tremendous scope for temperamental differences in creative scientific research. Pasteur's work covered an enormous range, including the foundation of the science of crystallography as well as his better-known pioneering in microbiology and immunology. He also was the archetype of the scientist as a public servant, discovering the technique of partial sterilization by "pasteurization" while attempting to improve the notoriously doubtful quality of French beer. By contrast, Michelson's achievement rested almost entirely on the utmost refinement of laboratory work in the measurement of the speed of light and the development of new instruments and techniques in physical optics. But Michelson's effect was quite as far-reaching as Pasteur's, since he laid the groundwork for much of modern theoretical physics.

Another paperback series pointed toward the schoolroom is entitled "Foundations of Modern Biology" (Prentice-Hall, each $1.50). Each hundred-odd-page volume concentrates on a single topic, giving it fuller treatment than is possible in the average college text for an introductory biology course. Typical titles are *The Plant Kingdom*, by Harold C. Bold, an outline of classification, structure, and methods of reproduction; *The Cell*, by Carl P. Swanson, covering the basic organizational unit of living matter; and *Animal Growth and Development*, by Maurice Sussman. The serious amateur of natural history will find in this series information on specific fields, including the latest research.

The increasing group of amateur microscopists will have a special interest in *Milestones in Microbiology*, edited by Thomas Brock (Prentice-Hall, $3.95). Here, abbreviated and well annotated, are most of the major papers in this fascinating field, from van Leeuwenhoek's first description of "several sorts of little animals" in a drop of water, through Robert Koch's classic "Methods for the Study of Pathogenic Organisms," on to Fleming's discovery of the bactericidal effect of *Penicillium* mold. Neither a text nor a history of microbiology, this book is a good introduction.

SPECIFIC groups of animals and plants have come in for attention—one definite plus value of the spate of paperbacks. One of the better specialized volumes is *The Molds and Man*, by Clyde M. Christensen (Minnesota, $1.75). The fungi, all 90,000 of them, are among the most interesting of plants, and both easy and rewarding to study. Christensen writes of them with an enthusiasm that borders on gusto, whether he is discussing the unique combinations that compose lichens or explaining that the flavor of Camembert cheese derives from two molds, one a *Penicillium*.

MR. GEROULD, who reviews regularly for NATURAL HISTORY, here adds to his paperback science book survey.

Insect Life and Insect Natural History, by S.W. Frost (Dover, $2.25), basically a college level entomology text, is a useful supplement to standard field books; while *Molluscs*, by J.E. Morton (Harper, $1.40), can serve similarly for the devoted shell-collector. Neither qualifies as bed table reading.

So many good books have been written about ants that another would hardly seem necessary. Nevertheless, *The Ants*, by Wilhelm Goetsch (Michigan, $1.95), *is* a good book, particularly in its descriptions of ant behavior, which the author has observed in many parts of the world. *The Birds*, by Oskar and Katharina Heinroth (Michigan, $1.95), in the same Ann Arbor series, casts a broad net to gather in a variety of facts, and is at its best in relating bird structure to bird behavior. *Reptiles: Life History, Evolution, and Structure*, by A. Bellairs (Harper, $1.35), has value as a systematic account of this class but, again, this work is for reference.

Two good but specialized field books are *How to Know the Ferns*, by Frances T. Parsons (Dover, $1.25), and *California Spring Wildflowers*, by Philip A. Munz (California, $2.95). The Parsons book, originally published more than 60 years ago, maintains its value through the simple accuracy of its drawings. The Munz book, based on the California littoral, is a cause for jealousy on the part of residents of other areas—a good text and nearly a hundred well-chosen and handsomely reproduced color photographs back up its black-and-white drawings.

METEOROLOGY is perennially attractive to the curious amateur, but books on meteorology are all too often overdetailed for the beginner. By focusing on the more spectacular aspects of weather, Louis J. Battan, in *The Nature of Violent Storms* (Doubleday, 95¢), manages to concentrate a large amount of modern weather science into comparatively few pages and to do so interestingly. Weather plays its part in *Water: The Mirror of Science*, by Kenneth S. Davis and John A. Day (Doubleday, 95¢), a truly imaginative piece of science popularization. The authors discuss the role of water in many different sciences, as well as the extraordinary physical and chemical properties that make water essential to life and a dominating factor in both the human and geological history of the earth.

The same interdisciplinary approach distinguishes another in the "Science Study Series," *Waves and the Ear*, by Willem A. Van Bergeijk, John R. Pierce and Edward E. David, Jr. (Doubleday

95¢). Starting with the physics of sound, these scientists from the Bell Laboratories go on to the physical and neural mechanisms of hearing in animals and man, and to the sonic structure of speech. A short epilogue on the reproduction of sound, incidentally, contains the final and authoritative word on "hi-fi": ". . . the New York Philharmonic or the Boston Symphony cannot be transferred perceptually to the living room."

As might be expected, the 1959 Darwin centennial continues to provide impetus for authors and publishers. One of the more provocative products is an essay by an Oxford botanist, *Darwin's Place in History*, by C.D. Darlington (Macmillan, $2.00). The social sciences, according to this writer, took their modern form from Darwin's great disciple, T.H. Huxley. Yet Huxley, like Darwin, was unwilling to accept the human implications of the doctrine of natural selection: hence social scientists since his day ". . . sailed on their own happy voyage with their own cargo of philosophy, but unassisted by any scientific chart or compass. . . . Darwinism, a belief in the evolution of animals, is an article of faith in the Soviet Union, but Social Darwinism, the application of the principle of natural selection to man, is as much a heresy as it is with Western social scientists."

Animal Species and their Evolution, by A.J. Cain (Harper, $1.35), gives an account of modern methods of classification with particular reference to the different kinds of speciation and evolutionary relationships; it is an admirably lucid presentation of an almost incredibly complex subject. *Natural Selection and Heredity*, by P.M. Sheppard (Harper, $1.35), shows how modern knowledge of the principles of heredity has both modified and broadened our conception of evolution; while *The Mechanism of Evolution*, by W.H. Dowdeswell (Harper, 95¢), covers much of the same ground with particular reference to experimental observation of evolution in action. *Genetics is Easy*, by Philip Goldstein (Viking, $1.45), is the kind of do-it-yourself title, which usually warns off the serious reader. In this case, alarm is unwarranted, for the book is a very clear account of the basics of heredity (with only minor journalistic fanfares and flourishes).

Unabashedly journalistic is *Adventures with the Missing Link* (Viking, $1.65), a collaboration of anatomist Raymond A. Dart and newsman Dennis Craig. Dr. Dart—who found the first fossilized remains of a primitive African creature dating somewhere between the apes and man—has a fascinating story to tell of his various discoveries and his many vicissitudes before the full acceptance of his work. He and his collaborator are as happy reconstructing the can-

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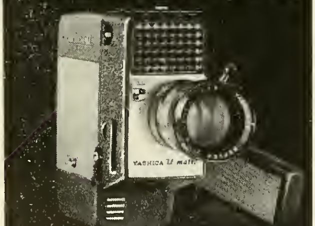

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nibalistic habits of Australopithecines as in recalling the slightly less lethal behavior of embattled anthropologists.

Among the earliest nature books were the medieval bestiaries, omnivorous compendiums of observation, travelers' tales, and pure mythology. *The Bestiary,* translated and edited by T.H. White (Putnam, $1.45), comes from a twelfth-century Latin manuscript and retains the flavor of the original's wide-eyed wonder at the diversity of creatures. The editor, a notable medievalist in his own right and author of *The Once and Future King,* has selected more than 125 illustrations from manuscripts to embellish the text, and has contributed footnotes that are informative and entertaining.

Unicorns and fire-defying salamanders, however, are not mandatory for the creation of a bestiary. *Nature Parade,* by Frank W. Lane (Fawcett, 50¢), collects facts from serious scientific sources and manages to be quite as marvelous as any medieval invention. Not the least wonderful member of the animal kingdom, according to Mr. Lane, is man—who can generate 8½ horsepower, exert a bite of 534 pounds pressure, and eat a meal consisting of a raw sheep, a suckling pig, and 60 pounds of prunes.

Another of man's accomplishments, unique in the animal kingdom, is his ability to devastate his own environment, either loudly in a matter of milliseconds or quietly over the centuries. The latter type of ruin, usually accomplished with such weapons as saws and plows, can be quite as final as the blast wave and the mushroom cloud. How this can be so is the theme of John H. Storer's *The Web of Life* (New American Library, 50¢), a primer in ecology—the study of the labyrinthine interdependences of the earth and the living things upon it. The conclusions it draws are as important—and in some ways more immediate—than the cold war headlines in today's newspaper.

Two very different classics in modern "nature writing" are available in "Explorer Books"—a series notable for physical quality and readability. *Flowering Earth,* by Donald Culross Peattie (Viking, $1.45), calls itself "a biography of the plant kingdom." Mr. Peattie, a better naturalist than prose-poet, is most interesting when his subject matter can be glimpsed through the pale-purple gauze of his verbiage. *The Outermost House,* by Henry Beston (Viking, $1.25), is perhaps the kind of book Mr. Peattie intended to write: sensitive, direct, poetic without poesy. It tells of a year spent quietly between sky, land, and sea on the dunes of the Atlantic side of Cape Cod, with little except the birds, the surf, and the weather for company.

One of the great field naturalists o

all time comes alive in *Audubon's Journals*, edited by Maria Audubon (Dover, 2 vols., $4.00). Audubon, besides being a dedicated naturalist, was also an indefatigable traveler. (He once walked 165 miles in three days, much of the distance through ankle-deep water.) What emerged from his journals and from the short, overpious biography by his granddaughter is an extraordinarily vivid picture of the American land in the early days of the Republic—a land of growing commercial cities, of struggling frontier settlements, and always beyond them the wilderness. Audubon saw it all and set much of it down in words less artful but quite as alive as his more widely known drawings.

Audubon's journals, out of print for many years, are a most worth while addition to the paperback shelf. Even more rewarding is another journal for which we can also thank the publishers of soft covers. Henry David Thoreau's journals filled thirty-nine notebooks in manuscript and fourteen volumes when published and, probably because of sheer bulk, remain a neglected masterpiece. *The Heart of Thoreau's Journals*, edited by Odell Shepard (Dover, $1.45), is a standard selection in manageable size. In many ways, Thoreau's genius and originality show forth more clearly in these short diary entries than in his longer and more organized books and essays. His greatest gift as a writer was to speak his thoughts simply and with absolute clarity; his best sentences say more than other men's chapters. From a book almost totally quotable, let one paragraph suffice:

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In connection with the review of science paperbacks, *above*, The American Museum of Natural History takes pleasure in announcing that a new series of soft-cover editions, "The Natural History Library," has been initiated. With Museum scientists co-operating as advisers, Doubleday Anchor Books last month published the first thirteen reprints in a series of classic studies in the natural sciences. Some of the titles are being especially revised for this series; most will have forewords written by members of the Museum staff. Ranging widely through the natural sciences, the selections focus on man in his environment.

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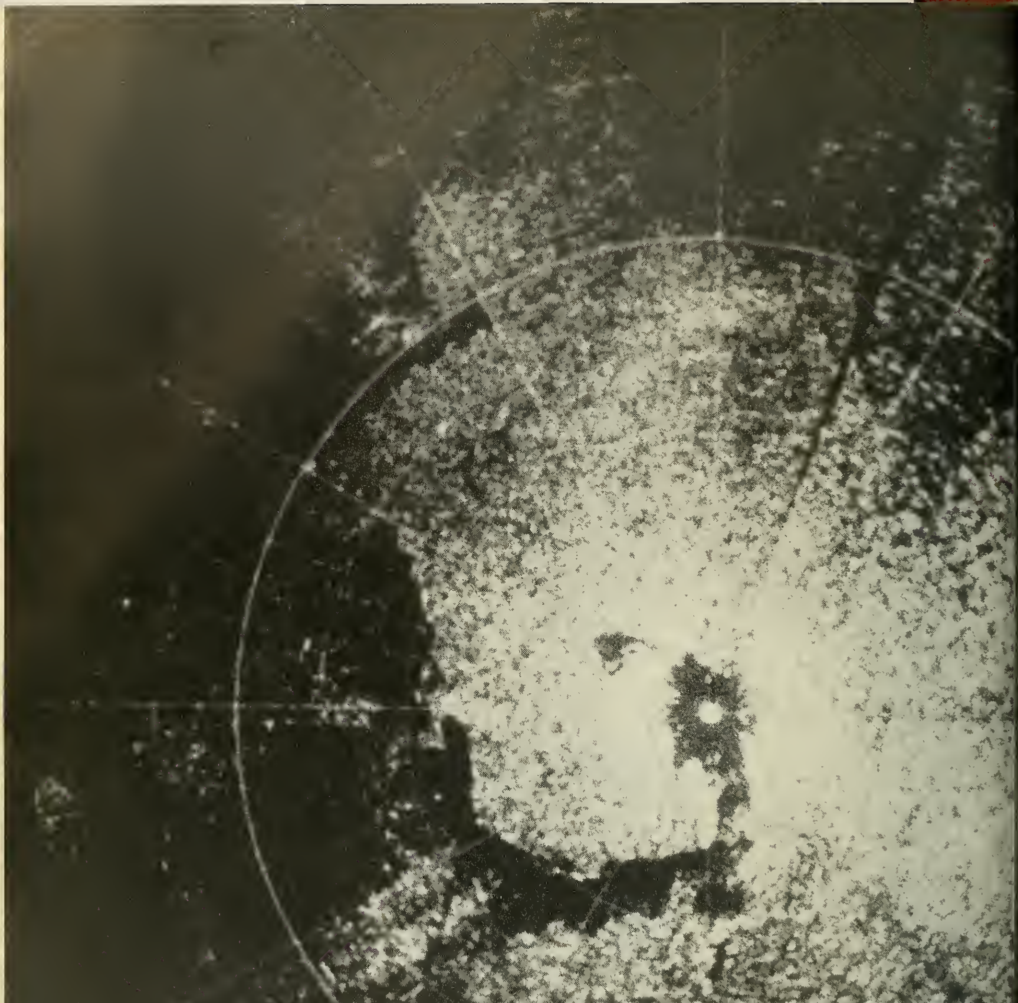
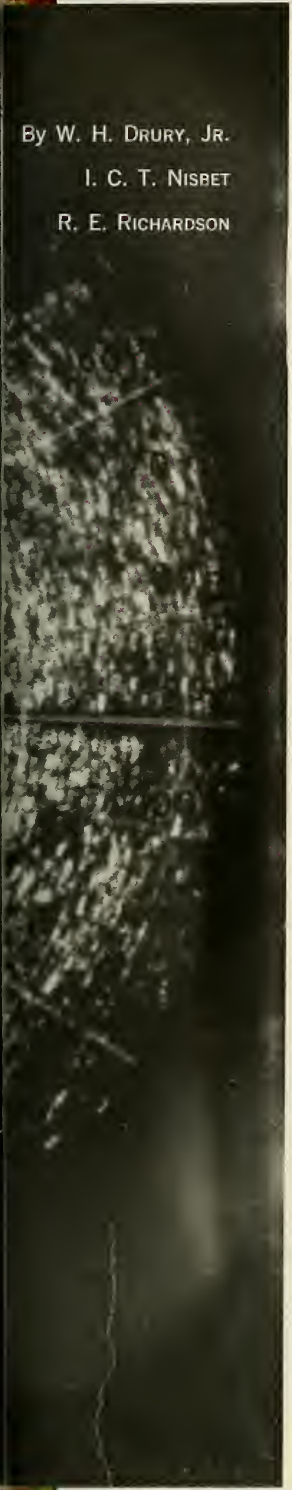


Snowlike targets seen outlining coast of Massachusetts are "angels"—echoes of birds on a radarscope, photographed on night of unusually heavy movement.

By W. H. Drury, Jr.
I. C. T. Nisbet
R. E. Richardson



The Migration of "Angels"

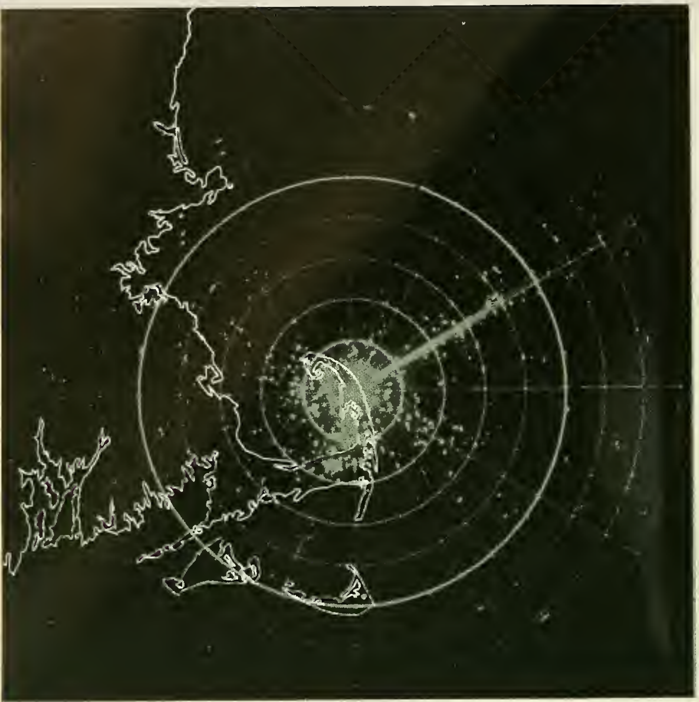
Radar offers new data on bird movements

Most people have a general understanding of how radar works, and many have seen pictures of a radarscope, or Plan and Position Indicator (PPI). As the radar beam—which is roughly analogous to the sweeping beam of a lighthouse—passes a target, be it ship, airplane, or even bird, that target is "illuminated." With radar, the illuminated target appears as a bright spot on the PPI scope, and the target's distance and bearing are thus shown on a "map" of the area around the radar installation. Many of the bright spots that appear on the modern PPI scope are readily identified. Still, particularly with high-powered radar, there are often many small, unidentified spots. Because these spots do not move as expected targets would, they have come to be known to radar observers as "angels." A photograph of a PPI scope of the experimental radar at South Truro, on Cape Cod, is shown at the left. In the picture, the Cape appears dark against the large number of light spots, or angels. These targets, as it happens, are birds.

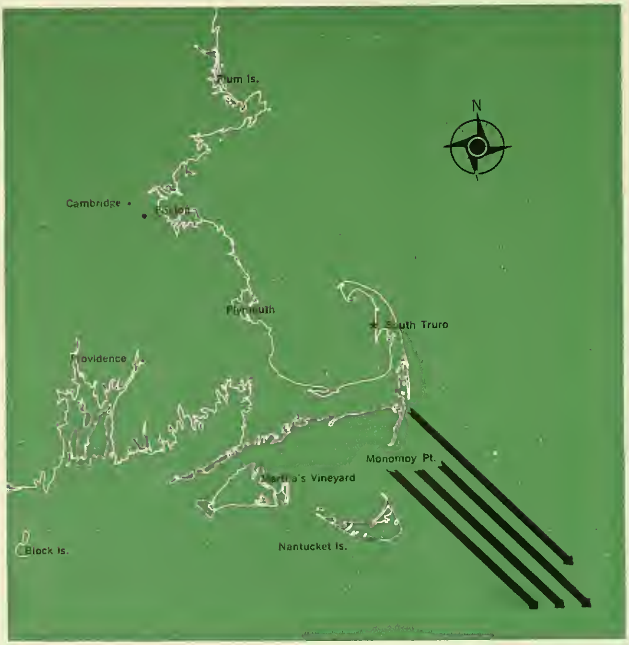
Argument as to the nature of angels has raged ever since these cryptic targets were detected on the south coast of England in 1940 and 1941. Early experimental radars picked up gulls, herons, and gannets, all of which are very large birds. The British ornithologists Lack and Varley published a paper in 1945 on the detection of gannets at coastal defense radar installations. But, despite this and many other articles describing the appearance of birds on radarscopes printed soon after World War II, most radar operators were (and still are) unwilling to believe that birds could be responsible for the displays of angels. Instead, these spots have usually been attributed to little-understood meteorological phenomena, and so dismissed.

Only in the last few years has the circumstantial evidence pointing to birds as the major cause of angel displays become overwhelming. And only in 1957 was systematic experimental evidence produced. That year, a team of research workers at M.I.T.'s Lincoln Laboratory, including one of the authors of this paper, conducted a year-long experiment that demonstrated that most angels are due to birds. The group then devised a circuit that would filter out radar echoes corresponding to targets the size of birds. When this circuit was inserted in the experimental surveillance radar installation at South Truro, Massachusetts, the angels disappeared.

Previous to this 1957 experiment, however, several studies of the daily and annual migrations of angels were published, showing just how valuable radar could be to the ornithologist. In 1956, Emil Weitnauer verified the suggestion that swifts regularly spend the entire night on the wing. After tracking angels in the night sky over Switzerland, he was eventually able to intercept the targets in a small airplane, and found that they were indeed swifts. E. Sutter, another Swiss ornithologist, published the first radar studies of bird migration in 1957. In England, the radial dispersal of starlings and rooks was studied by W. G. Harper in 1957; while that of New World blackbirds was observed in Michigan by Elder in 1957, in Texas by Ligda in 1958, and in Tennessee by Cypert the same year. The movement of these gregarious birds from their common roosts, as tracked by radar, resembles the exten-



Radarscope on fall afternoon, with a map outline added, shows unidentified spots east and south of Cape Cod. When data from consecutive observations were analyzed, *below,* "angels" were seen to be shore birds off for South America.

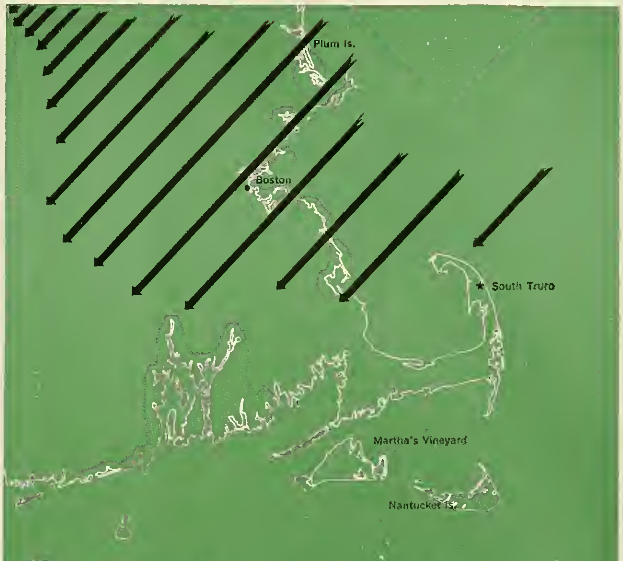


sion of smoke rings. More recently
Lack has published reviews of rada
research on bird migration, describin
the year-round migration movement
over the east coast of England, and interpreting radar observations by relat
ing weather to passerine migration.

As all of this work has shown, rada
can provide much interesting information on a variety of bird habits
Migration that occurs at night, or a
altitudes too great to be seen from th
ground, has heretofore been an orn
thological unknown. The studies mad
so far have revealed in a most vivi
fashion the tremendous volume of mi
gration that can take place, so to speak
behind the unaided human observer
back. One of the most spectacular ex
amples is Lack's discovery of a hug
spring flight of chaffinches, skylarks
and other winter visitors, from Eng
land eastward to the Continent—
phenomenon that had barely bee
suspected by earlier students.

Radar's remarkable ability to trac
the movements of individual birds
and to display echoes of all the bird
in a wide area, promises early solu
tion to several long-standing problem
in migration today. Measurement o
the altitude of angels, for exampl
suggests that most small northwar
migrants fly between 1,500 and 6,00
feet—with a sprinkling of birds som
nights as high as 10,000 feet. Lack'
work shows that birds migrating fro
England across the North Sea to th
Continent do not correct for the dri
effect of cross-winds, but are deflecte
laterally from a more or less consta
heading, so that they move northea
when the wind is from the south, o
southeast when it is from the nort
We find vivid illustrations of the sam
type of wind-drifting of birds out t
sea off Cape Cod (illustration, *right*

Our own opportunity to carry ou
radar research on bird migration gre
from the previously mentioned exper
ment at Lincoln Laboratory, as pa
of the development of the SAGE A
Defense System. The team at Lincol
concluding that angels were birds, wa
able to relate daily movements of thes
targets to those of herring gulls an
ducks that feed off Cape Cod. The
apparently having solved the proble
of the angels, they were puzzled, i
March, 1957, to find a much larg
number of smaller angels moving b
night in a northeast direction. The
rightly concluded that this represent



Radar reveals that most fall migrants from Canada ignore coast and pass over mainland. Few birds cross over the Cape.

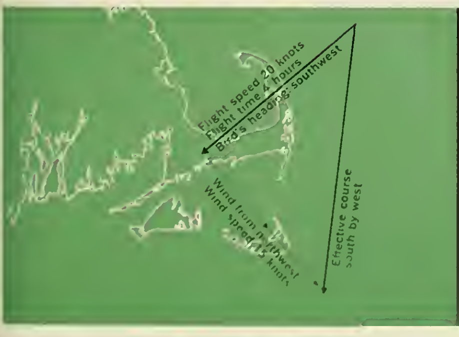
the spring migration of land birds, and that its detection by radar would interest ornithologists.

So far, analysis of nightly films—the PPI scope record of a whole night's migration can be compressed into a few minutes of film—has been concerned with three main problems. The first is chiefly statistical—the relationship between the true number of migrating birds and the density of angels on the screen. On a good night for migration, there may be 100 or more birds aloft per square mile. If every bird were detected, the entire scope would be swamped by echoes. The compensating factor, which resolves this difficulty, is due to a phenomenon that is well shown in photographs of the radar screen. As distance increases, progressively fewer birds are detected, so that the pattern of echoes thins out steadily until the density of angels can be counted easily. This is because the radar's sensitivity falls off at longer ranges. Preliminary results show that, if the density of birds is constant, the number of angels is roughly halved in each ten-mile step from the center of a PPI scope.

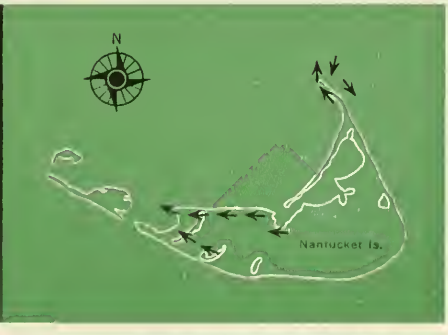
Thus one may count the number of angels in a given area, multiply this number by a constant factor, and so obtain a reasonably reliable estimate of the total birds passing over the area. Having obtained a count of angels in this way, we made an independent estimate of the number of passing birds by counting those birds visible through powerful binoculars trained on the moon's face and applying a mathematical correction to this visual count. Although such a method of sampling is probably less accurate than techniques of observing migrations visible during the day, the results achieved by scope and visual methods agree very well.

We decided that each angel corresponds to something between three and 12 birds when the angel is at approximately 20 miles. Because radar should easily be able to detect individual birds at such short ranges, this greater-than-unity result suggests that many of the birds travel in small groups. At the same time, it is unusual for the visual observer to see even two small birds cross the moon together. We therefore conclude that these night flocks must be a good deal more scattered than the large flocks of many daytime migrants.

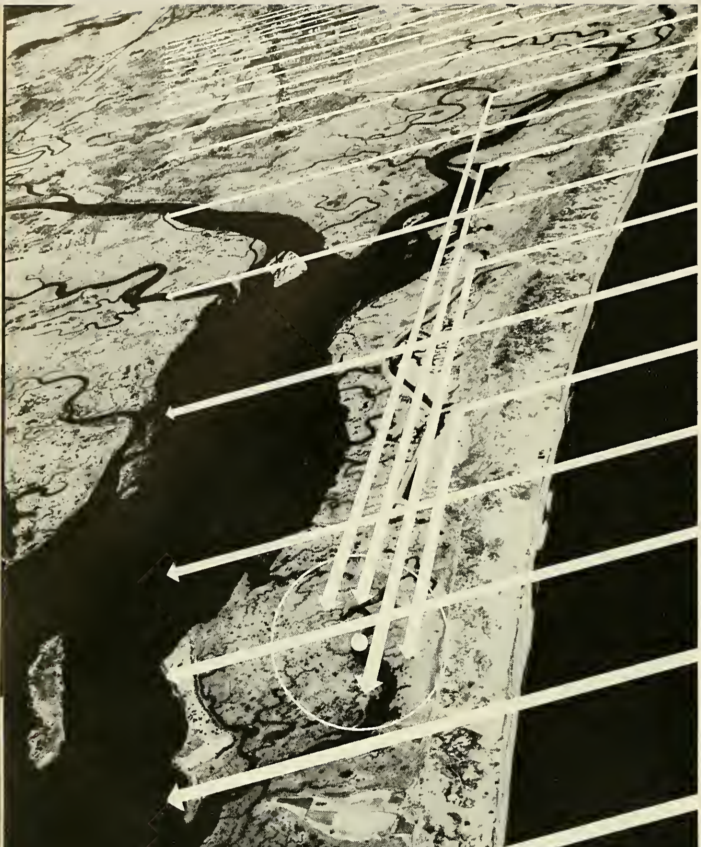
Our second problem concerned what radar tells us of the behavior of birds when they reach a coastline. On a night of heavy migration, the density of birds overhead is approximately one per acre. Thus, migrating birds must be greatly concentrated before a ground observer will be aware of the fact that a migration



Actual flight path of bird is plotted, *above*, to show the effect of cross-wind on bird's original course toward coast.



Daytime movements of wind-drifted night migrants, noted by ground watchers, suggest birds then head for mainland.



Classic error of ground observer at coast is shown by imaginary situation on Plum Island, Massachusetts: a man located in circle will report four birds following coast for each one crossing. Radar shows reverse is actually true.

has taken place. Students of migra
tion, being naturally attracted b
large numbers, have in the past sough
out places where migrants are concer
trated by certain natural topographi
features. Van Dobben, in 195
showed how these concentrations ma
occur under certain circumstances i
Holland. He pointed out that if
group of birds, migrating on a broa
front, meets a coastline, perhaps on
in four or five birds will turn and mov
along the coast, while the rest cros
without deviation. The single o
server, stationed along the shore an
counting the birds coming down th
coast, might well report a heavy coas
wise migration and little evidence
birds crossing the coast, because h
sees most of those birds that hav
turned from all the way up the coa
and only a few that cross the beac
where he is. From such observation
the conclusion has been drawn i
many parts of the world that migran
come from inland to the coast and fo
low it as a migratory route. (This co
clusion has been especially prevale
in the eastern United States.)

THE turned birds, if they contin
along the coast, will eventually b
concentrated by the accidents of t
pography, and such places of conc
tration will have become familia
students of migration. Quite of
these places also concentrate the
and unusual birds of interest to
teurs. For example, the east coast
Sweden—on the main migration rou
—is not nearly so good a place to fi
stragglers from Siberia as the sm
islands off the Norwegian coast,
Fair Isle, off the north coast of Sc
land. And the famous names, Helg
land, Monomoy Point, Nantuck
Cape May, Island Beach, reflect oth
such misleading samples.

Our radar studies showed hea
movements pouring across the coa
spring and fall, without any reacti
to the coastline except by a very sm
percentage of the birds. In the fall,
fact, songbirds often appear pouri
south out over the Atlantic in wh
would seem to be a dangerous wa
This finding, in itself, offers a n
problem in migration that was n
even suspected before the use of rad
The fate of these sea-bound songbi
populations is not presently known,
though there is a hint that, towa
dawn, birds turn west and northw
as if seeking the shore. This agr

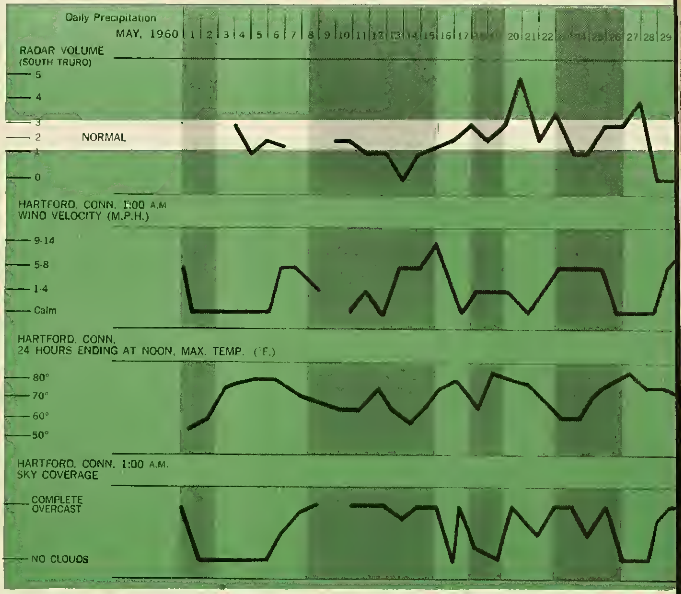
with the observation of those who have watched daylight movements along the New England shore. These observers often report birds coming in from the sea all through a fall day, heading in a northwest direction—when birds "should" be heading southwest at this time year.

In contrast to the previously held belief that birds come down to the coast and then turn to follow it as a route. our radar studies show that between 10 and 50 times as many small birds—coming from Maine. Nova Scotia, and Newfoundland—migrate southwest. over Cambridge and the inland areas of Massachusetts. as pass over Cape Cod. This is at least circumstantial evidence that migrant populations as a whole tend to follow routes away from the coast. Banding results seem to confirm this: at inland sites in the fall. adult birds may nearly equal the immatures; but coastal banding stations have long known that they should expect 95 per cent or more of the fall population to be immatures—as if the older birds seemed to "know better."

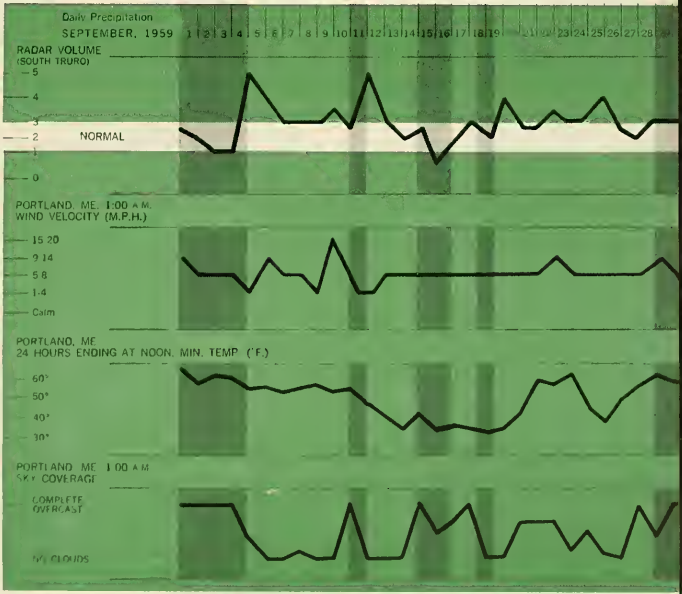
Spring radar observations show heavy migrations leaving Cape Cod in a northeasterly direction toward Nova Scotia without any hesitation at the oastline. although there are even heavier movements inland at such mes. We may conclude. then, that the main populations select their general movements to avoid the dangers of being blown out to sea; and although the average bird probably pays no heed as it passes over the coast, the actions of individual birds—when watched in detail—may be different.

Still another group of birds ignores the coastline for their own special reason. Radar sometimes shows dense. fast (40 knots) targets flying out to sea on southeast courses in the late afternoon. especially about an hour before rain squalls. These targets occur particularly from mid-July until mid-October. and they are sandpipers and plovers on their non-stop flight to the Lesser Antilles and South America. Sportsmen on the outer islands, such as Barbados. have long known that hese shore birds came in. but they did not know how far [illegible] had come.

The third problem we have studied s the direct effect of weather on migrant birds. It has long been known, of course. that migrant birds are greatly affected by weather changes,



Weather's influence on migration in spring, graphed above, reveals a close correlation between days of state-wide rain and bird traffic as seen on radar. Peaks are correlated with clearing after rain; clouds and wind seem secondary.



Fall migration pattern in relation to weather conditions, *above*, shows close similarity to spring's. Note that cold snap this September, however, brought southerly movements of kind that are more commonly found during October.

and that night migratory movements are correlated with the movements of air masses. But the collection of precise facts and fine details has been greatly handicapped by observational difficulties. Radar now provides a reasonably good quantitative measure of nocturnal migration, and opens the way to a new study of the problem. Lack in England and Sutter in Switzerland have already provided important data on the relation between weather and migration in Europe, and the first results are beginning to come in from North America.

The chief source of our weather information is the U.S. Weather Bureau's daily map that shows the 1:00 A.M. readings of temperature, cloud cover, precipitation, and strength and direction of surface wind for a wide range of stations. Actually the wind at a height of 1,000 to 4,000 feet is more relevant to the movement of birds than the surface wind, but upper air movements can be deduced with fair accuracy from the map's isobars while, in special cases, we have obtained aerosonde readings from local weather stations. Since we can measure the birds' flight directions and the speeds, and we assume that they left shortly after dark, we can trace them back to the approximate places where they started to migrate. We may then determine the weather that affected birds before and during that flight.

A summary of outstanding interactions between weather and migration over certain areas of New England in May and September, 1959, our first year of operation, will give some idea of the possibilities opened up through radar techniques. In general, our results confirmed conclusions made as long ago as 1888 by Wells Cooke: the nights of the largest spring migration were those of clear skies and steady movement of warm, tropical air in a northeast direction from the Middle Atlantic States. We have long known that migrants usually stop when they meet precipitation, heavy cloud cover, or turbulent winds. An example is on the night of May 7/8 when favorable conditions existed to the south but ended sharply at the Massachusetts-Rhode Island border. Large numbers of birds appeared in Rhode Island while, to the north and east where the weather was cool and overcast, relatively few birds appeared.

DR. DRURY, of the Massachusetts Audubon Society, collaborated with his physicist colleagues, Dr. Nisbet and Dr. Richardson, in working out the problems involved in this study.

The unaided ground observer could properly have interpreted the events of that night. But of special interest is the frequency with which radar results disagree with the impressions of ground observers, who judge the strength of the night's migration by counting the grounded migrants seen the following day. A vivid example of the dangers of this method was given us on the days 9 through 14 May. The nights of May 9/10 and 10/11 were increasingly good for migration, and the radar recorded very dense movements of birds. But ground field observers found only insignificant numbers of new arrivals on 10 May and 11 May. On the succeeding three nights, May 11/12, 12/13, and 13/14, the weather was still warm with favorable winds, but conditions in the Central Atlantic States were too cloudy to be ideal for the start of migration, while a stationary front over eastern Massachusetts produced heavy clouds and rain—a major barrier to migrating birds. Field observers in New England found the largest number of birds of the spring of 1959 after the night of 13/14 May. But the radar showed relatively small numbers of birds had been migrating that night! These results suggest that conventional techniques of field observation overemphasize the importance of "spectacular" waves of migrants, which can be produced for enumeration by the premature interruption and grounding—by rain—of even a small movement of birds.

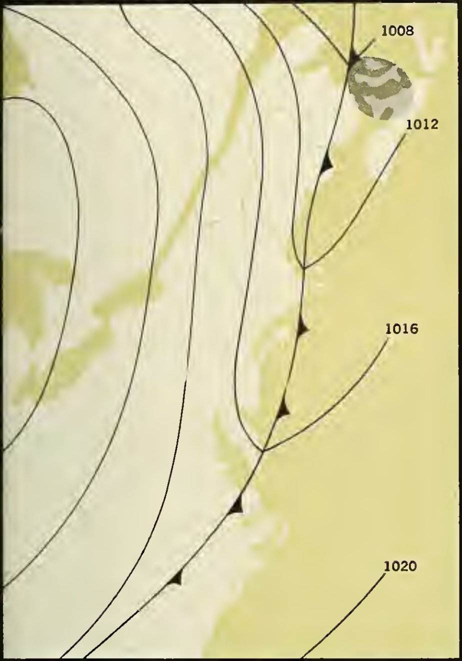
Both the New England spring and fall are celebrated for their violent contrasts in weather. The spring arrival of a cold front brought new phenomena of outstanding interest. On three occasions when such weather occurred (the nights of 8/9, 14/15, and 22/23 May, 1959), the radar showed a steady *southward* movement, with many birds even heading southeastward out to sea. This parallel with autumn movements is reflected in the ground observations. In southern Rhode Island, where spring migration is always sparse—the autumn migration is much more interesting because the east-west coastline interrupts some birds' southward flight—the best days of the spring were 10, 16, and 23 May, 1959. It is easy to suggest that there may be a selective advantage for insectivorous birds—having advanced too rapidly in the spring and being overtaken by weather that threatens their food supply—to react by returning southward immediately. The reaction was certainly a rapid one. On th night of 22/23 May, when the cold front crossed over Cape Cod at about 11:00 P.M., the northeastern movement of birds was replaced, first, by a milling movement as the squalls of rain associated with the front passed, and then by a southward movement—all in a period of about two hours.

Radar has revealed similar reverse migration in the autumn. In September, 1959, the birds were moving north east during periods of warm weather as tropical air entered from the southwest. The records of the nights of 9/10 and 12/13 September show just how delicately the movements of the birds are adjusted to weather conditions. On these nights, there were cold fronts lying along an east-west line over the Gulf of Maine. In the cool, Canadian air to the north and east of the front, radar showed birds moving southwest from Nova Scotia while, to the southwest, in the warm, tropical air lying over Rhode Island and Connecticut, the birds were moving in a northeast direction from Long Island toward Cape Cod. Such radar observations solve the ancient dilemma between the theory (supported by field observations) that, in the fall, birds should be going southwest, and the hard facts of banding recoveries that often show a fall movement to the northeast. For the biologist, however, a further problem is raised: if birds can reverse movements so easily, what internal factors control orientation?

Like most new tools of science, radar has already raised more ornithological questions than it answers. But, above all, it has given us an unequaled opportunity to relate actual migration to the experiments provided by the foibles of New England weather, and to watch with some precision a natural phenomenon that has intrigued men for at least as long as written records have existed—the movement of birds in the night sky.

WEATHER CONDITIONS that influenced migrants during May, 1959, are shown. *right.* Radar revealed modest volume of flights, but ground observers counted record number of rain-grounded birds

MAY 7/8: Only light migration in northern New England.


1008
1012
1016
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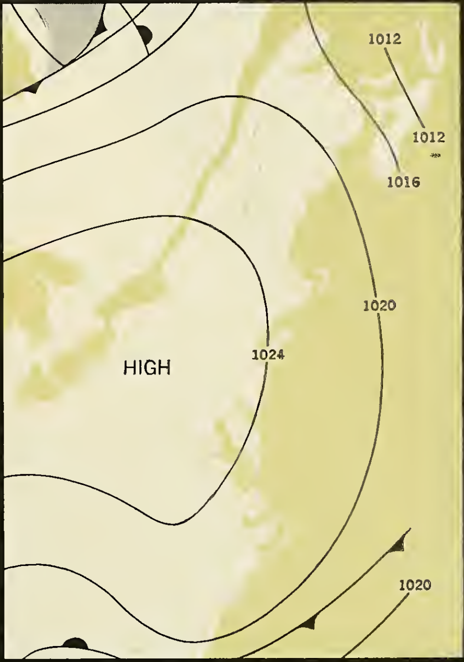
MAY 8/9: Cold front from north brought reverse movement.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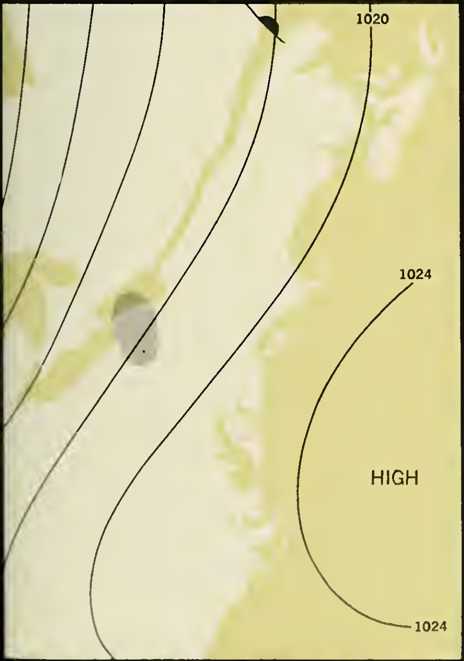
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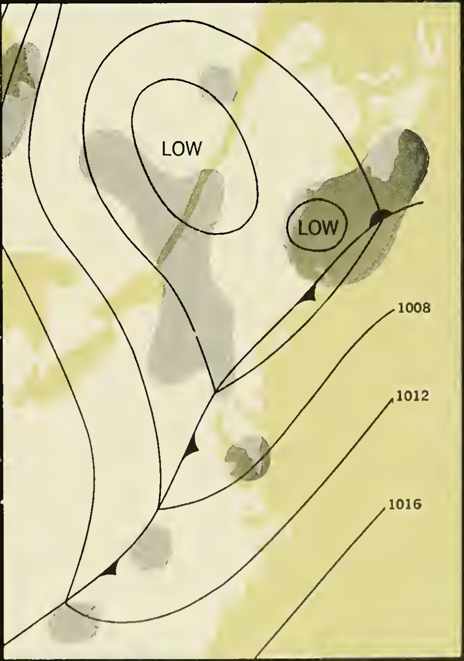
MAY 10/11: Conditions generally favorable to migrants.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LOW
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MAY 13/14: Rain grounded migrants across New England.

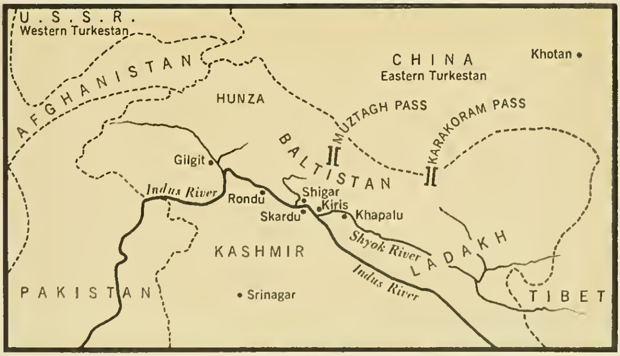
The People of Baltistan

A transitional culture of Central Asia

By James Hurley

High Asia was introduced to much of the world only seventy years ago in a book by E. E. Knight called *Where Three Empires Meet.* Although one of these "Three Empires"—that of the British—has now passed away, recent moves in High Asia by the Chinese have revived interest in the area. Yet knowledge of this remote region has remained remarkably unchanged since the latter nineteenth century. Knight's work, which became almost a textbook for more than a generation of British school children, was mainly concerned with Hunza, a tiny mountain principality that was situated athwart the meeting place of British India, Russia, and China. But Knight also touched briefly on Baltistan, or Little Tibet, a fascinating and still relatively unknown region lying off the main routes and passes, then, as now, out of the main political arena of the contending powers.

Who are the Balti and why is their country sometimes called Little Tibet? Briefly, the Balti are of mixed Mongoloid and Caucasoid racial stock, they speak a language of the Tibeto-Burman family, and they are followers of the prophet Mohammed. This unusual combination of race, language, and religion probably exists nowhere else in the entire Himalayan and trans-Himalayan region. In fact, Baltistan is one of the important transition areas between East and West: it marks the farthest westward extension of the Tibetan language and culture, and quite possibly the farthest eastward penetration by the Caucasoids into one of the most formidable mountain bulwarks on the world's surface. One can well imagine how painfully slow must have been their progress if one looks at a relief map that shows the successive complex of the Hindu Kush, Pamir, and Karakoram ranges, which thrust innumerable ice-capped ramparts, high glaciers, and deep gorges in the way of any intruders into the region.


U. S. S. R.
Western Turkestan
AFGHANISTAN
CHINA
Eastern Turkestan
Khotan
HUNZA
MUZTAGH PASS
KARAKORAM PASS
BALTISTAN
Gilgit
Indus River
Rondu
Shigar
Kiris
Skardu
Khapalu
Shyok River
LADAKH
KASHMIR
Indus River
PAKISTAN
Srinagar
TIBET

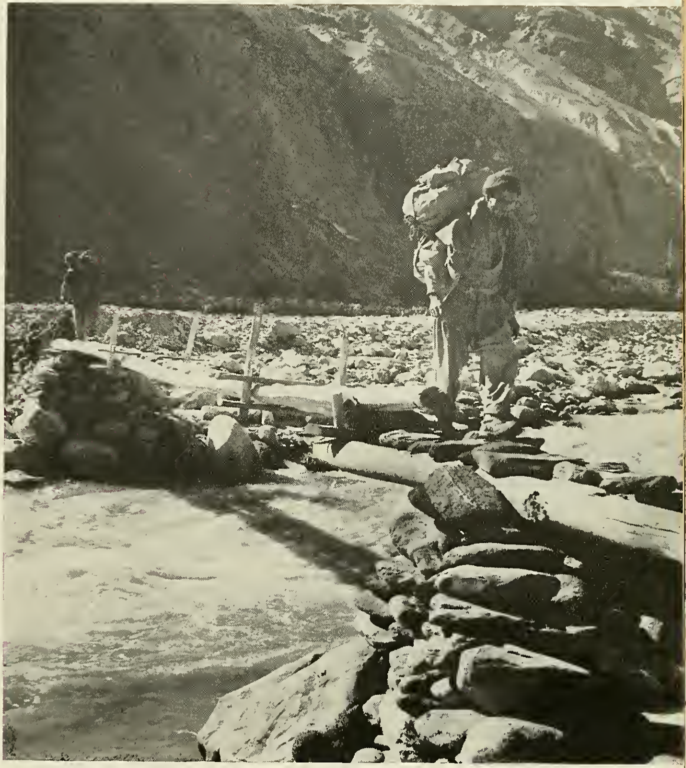
Raised canal near Skardu, capital of Baltistan, is three miles long. Dating from the 1500's, canal was reputedly built by Skardu's last Buddhist queen.

But do we have any idea how and when these light-skinned people with origins so similar to ours reached this region in the first place? Generally, we do not. Possibly they were a later offshoot of those Aryan tribes that streamed from their upland homes north of the Iranian Plateau, into northwest India across the Khyber and other low passes to the southwest about 1500 B.C. Balti tradition has it that some of the local rulers and petty chiefs are descended from the soldiers of Alexander the Great, but there is no evidence to support this and the claim seems to be almost completely in the realm of wishful thinking.

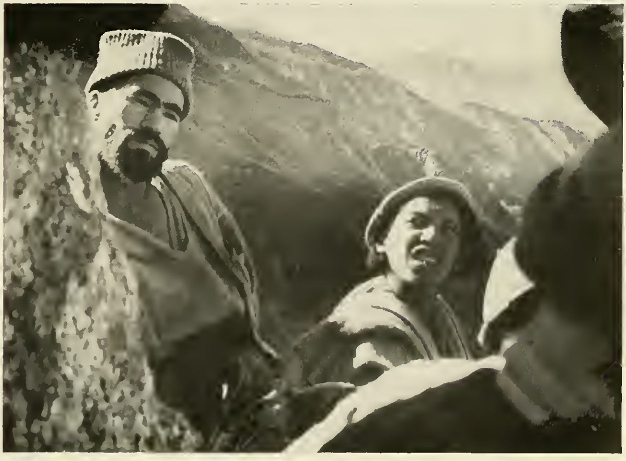
THE first references we find to the Balti occur in the reports by the second-century writer Ptolemy who, in his *Geography*, mentions "the Byltai" and "the Daradai." He gives no details of the former, but the latter seems clearly to refer to the Dards, a people of Caucasoid stock. The Dards now dwell mainly in the Gilgit region to the west of Baltistan, but also they constitute a fairly sizable and distinct minority within Baltistan. Herodotus, some 600 years earlier, had also referred to the area of the Dards when he wrote about the country of the "gold-digging ants" (creatures as big as dogs, who threw up gold while burrowing holes in the earth). Most authorities interpret the location of the area described in this passage as the Deosai Plateau, which lies largely within the confines of Baltistan. Until we learn of an earlier people, we can assume then that it was the Dards who constituted the original Caucasoid population of Baltistan, upon which successive layers of invasion, trade, and proselytizing have produced the present curious mixture.

WE next hear of the Balti people in the account of the travels of the seventh-century A.D. Chinese Buddhist pilgrim Hsüan Tsang. Aside from the fantastic legends that have sprung up about his trip (so delightfully translated recently in Arthur Waley's *The Monkey*), Hsüan Tsang's observations about the people, route features, and historical circumstances of the time still remain among the most valuable and sometimes the only

NARROW TRAIL SECTION juts from face of a cliff towering above Indus River.



BALTI PORTERS cross a bridge over a glacial stream. These streams become torrential in spring and summer, and may sweep away bridges, halting travel.



MAN AND BOY illustrate Caucasoid and Mongoloid Balti strains, respectively. The youth is wearing a round skull cap, characteristic headgear of the country.

HEAVILY LADEN PORTERS climb up steep southern slope of the 16,660-foot Skoro La, one of the many passes separat
the inhabited valleys from one anot

sources of knowledge—not only for remote places such as Baltistan, but also for many areas in India as well. Journeying from northwestern India to Baltistan in about A.D. 632. Hsüan Tsang recorded: "... after climbing precipices and crossing valleys. we go up the course of the Sin-tu [Indus] River; and then, by the help of flying bridges and footways made of wood across the chasms and precipices ... we arrive at the country of Po-lu-lo [Bolor or Baltistan]. It stands in the midst of the great Snowy Mountains. It produces wheat and pulse, gold and silver. Thanks to the quantity of gold. the country is rich in supplies ... the people are rough and rude in character; and as for politeness, such a thing has not been heard of. They are coarse and despicable in appearance ... their letters are nearly like those of India, their language somewhat different. There are about a hundred *sangharamas* [monasteries] in the country with something like a thousand priests. who show no great zeal for learning and are careless in their moral conduct."

Not a very complimentary passage, but it does provide us with facts on which we can almost surely rely. Although historical circumstances have changed greatly over the last 1,300 years. much of what Hsüan Tsang said is still appropriate. For example, the difficulties of the route along the deep Indus gorge between Gilgit and

Skardu are virtually the same. Hsi
Tsang's comment on the languag
especially interesting in that it n
refer to the Tibetan script (which
adopted from the Indian) and ther
indicate that Baltistan had alre
been subject to Tibetan influence
a considerable period. Whate
script was used—and we know alr
nothing of what it was—it has l
since been discarded (probably ab
the time of the Moslem conversio
being considered a relic of idola

Baltistan enters the picture ag
briefly but dramatically, in the eig
century annals of the T'ang Dyna
During the sixth and seventh ce
ries, China had been extending
sway over the western region—Tu

n—as it has been doing again in
odern times. In the latter part of the
enth century, the unified kingdom
Tibet arose, and what had been
til that time only a disorganized
llection of quarrelsome tribes sud-
nly became a major power with
ich the Chinese had to contend.

s the struggle that soon developed
for eastern Turkestan, Baltistan be-
me of critical importance—the only
e it has been so important in its
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y to Turkestan for the Tibetans be-
use, when taken, it would permit
m to attack the flank of the Chinese
rrisons around the perimeter of the
klamakan Desert, which were at
Kashgar, Khotan, Kucha, and Karashar. Between A.D. 696 and 741, the Balti, fearing attack from the Tibetans, sent several missions to the Chinese court. One of the results was the conclusion of a marriage alliance—always important in the East—between a Balti prince and a T'ang princess. The T'ang rulers also sent 4,000 Chinese soldiers in A.D. 722 to assist the Balti in repelling the Tibetan invaders. But all was for nought, and the Tibetans overran Baltistan in 737. Ten years later, in 747, the area changed hands again when a Chinese force re-established T'ang influence.

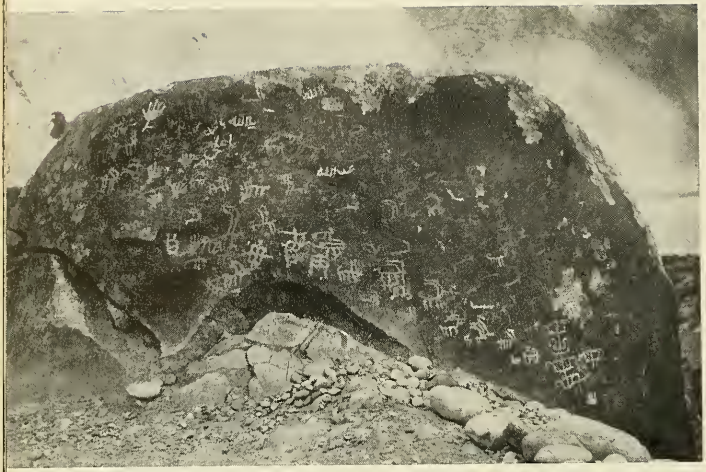
The year 747 was an important one in Central Asia, for that August a force of 10,000 Chinese, under the Korean general Kao Hsien-chih, crossed the formidable barrier of the Pamir and Hindu Kush to the west and wiped out the Tibetan garrison at Gilgit. The political importance of this event was great, for it came at a critical time in history and forestalled a tie-up between the Tibetans and the rapidly advancing Arabs on the west, who were already in western Turkestan. It is difficult to imagine how the face of Asia might look now had there been a joint Arab-Tibetan invasion of China. The Chinese march into Gilgit is equally remarkable as a feat of logistics. It marks the only time a major military force has crossed this continental divide between China and India, and it has been held to compare with, or even surpass, the great Alpine feats of such commanders as Hannibal and Napoleon.

However, the Chinese victory was only temporary: within a few years they were thrown out of Turkestan, not to return for more than a thousand years. In A.D. 751, Baltistan was permanently overpowered by the Tibetans. Thereafter, there are no references to the area in Chinese annals. In fact, for the next six centuries Balti history is almost a complete blank. We know nothing of how long the Tibetans stayed, what the nature of their rule was, or what cultural interpenetration took place. It has been surmised that the Tibetan occupation was relatively short and that the suzerainty exercised was nominal. This seems a reasonable premise in view of the great distance—more than 2,000 miles—separating Baltistan from Tibet's center, Lhasa. Of even more historical relevance is the fact that, by the end of the ninth century, Tibet's power—and with it that mountain nation's one serious bid to be a world power—had passed. But even during this brief period, we may assume that much of the racial admixture we see now in Baltistan had taken place.

The blank of the next few centuries is not even penetrated by Marco Polo. That notable medieval traveler and observer, when he passed several hundred miles to the north in the thirteenth century on his way to the court of Kublai Khan, made only the briefest reference to the mountainous area of Bolor lying to the south. He gave no geographic details of this region, but earlier students of his travels thought Baltistan might fall within it. The modern view, however, is that Polo meant only the country lying between the great bend of the Indus (at Gilgit) and the Pamirs.

Not until the end of the fifteenth century do we begin to get some sort of sketchy idea of the Balti in their present historical setting. It was then that the new Moslem rulers of Kashmir began to take an interest in their mountain neighbor to the northeast. The Hindu kings who had ruled Kashmir up to the middle of the fourteenth century may have exercised loose control over the Balti from time to time but, on the whole, Baltistan had probably retained its independence. Now the Moslem sultans looked at it possibly with an eye to linking up with eastern Turkestan, where the population had embraced Islam some time during or soon after the wane, in the ninth century, of Tibet's monarchy.

For unknown centuries before this Moslem influx, the Balti had been Buddhists. We know this mainly from carvings and graffiti on rocks—showing such typically Buddhist subjects as funerary monuments and bodhisattvas—which are still visible at several places in Baltistan (the large one near Skardu, shown on pages 22-23, is considered the finest example). We have no direct evidence as to when the Balti became Buddhists, but it appears to have happened sometime between the fourth and seventh centuries. Hsüan Tsang's reference to the priests and monasteries, already quoted, is the only positive clue. But these rock carvings also tell us something else: they indicate the existence of an earlier, pagan religion. Among the crude figures carved on the rocks, now little



Ibex figures are inscribed on a rock near Kuru. Carvings may be connected with animistic cults, earliest known religions of Baltistan's inhabitants.

more than traces, the figure of the ibex occurs most often. The meaning of these ibex signs, which are said to occur from Siberia to Palestine, is disputed among anthropologists. The theory that seems most current is that the symbol is connected with an early totemistic cult having the ibex as a sacred animal. Recent research tends to conclude that the domestication of the goat occurred first in these high regions of Asia: thus, it is not difficult to imagine how the ibex, the most lordly of the goat family, became an object of veneration. But local tradition and legend do not go back so far; they ascribe the depictions merely to the work of shepherd boys, or sometimes connect them with hunting. For example, after a local raja has killed a minimum of perhaps 100 or 200 ibexes to prove his prowess, each subsequent kill is commemorated with a carving. In nearby Gilgit, the carving of the ibex still takes place before the hunting season as a symbol of luck or expiation. One legend, from the adjoining area of Ladakh, has it that one of the incarnations of the Buddha is an ibex, while another declares that the ibex is connected with fertility, a figure being carved whenever a child is born to a couple who had sought divine intervention.

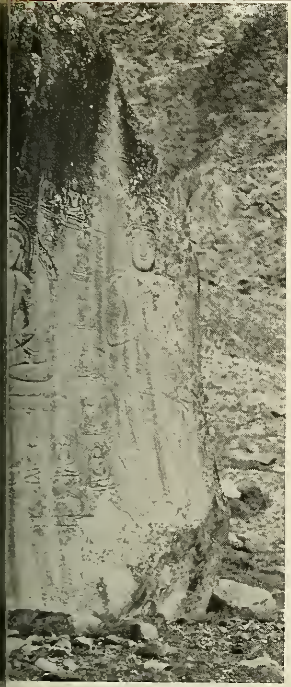
Between the development of these early animistic and totemistic cults and the adoption of Buddhism in the early centuries of our era, another religious system seems to have existed in Baltistan under the name of Bon. Essentially the worship of natural forces—earth, fire, and water (with which the colors blue, red, and white were associated)—it originally took the form of primitive shamanism. Although remnants of Bon beliefs still exist in Tibet, nothing is known about the religion's connection with Baltistan except that certain place names are believed to be associated with ritual names in the Bon religion.

One great legend survives that may yet prove an important key to the Bon as well as the Buddhist period of Baltistan's history. This is the Kesar saga. An epic poem dealing with the life of the mythical Tibetan King Kesar, it has been said to be to Asia what the *Iliad* is to Europe. Kesar has become the present-day national hero of the Tibetans, comparable to the British Arthur, the Hebrew David, and the Persian Rustam. In her book, *The Superhuman Life of Gesar of Ling*, the French Buddhist Alexandra David-Neel relates dramatically how the "yellow races" (Tibetan, Mongol, and Chinese) consider Kesar as a sort of messianic figure, or latter-day Genghis Khan, who will return some day to lead them against the whites. The Balti, fortunately, do not have that bent, but think of Kesar merely as a former Buddhist or pagan king. Their present Moslem faith forbids their attaching any religious importance to Kesar, but his hold on their imaginations is clear in the large number f physical features with which his na is still associated: "Kesar's gun," "I sar's horse," "the place where Ke r shot the arrows," and "Brugmo's ne lace" (Brugmo was the bride of Kes are some of them.

Gautama Buddha is depicted on r near Skardu. Date of this carving

In recent years, however, Kes s place in Balti folklore has been creasingly challenged by the name f Syed Ali Hamadani, one of the gr t Moslem figures of the fourteenth c tury, traditionally held to be resp sible for the conversion of Baltista o Islam. Although the survival of e lengthy and unwritten Kesar sag to recite it in its entirety takes fr n twelve to twenty evening sessions s strong testimony to Kesar's stay g power, it, too, seems to be disapp r ing under the pressure of increa d Islamic activity. During four suc s sive yearly trips to Baltistan, I fo d no one who knew the poem in its tirety. It was only with the consi r able assistance of a local raja th I managed to collect the epic last y r.

The challenger of Kesar, Syed li Hamadani, was a remarkable per n ality who combined the qualities of mystic, missionary, and practical e former. He was born in Hama n,



ıt at about A.D. 1000. Buddhism was
evalent from 4th to 14th centuries.

Moslems pray in the village of Goma, high in a valley of the Saltoro Range. Despite their diverse religious past, all Balti are now followers of Islam.

ersia. in A.D. 1314, the son of a local
vernor. He became interested early
life in Sufi mysticism, and turning to
avel as a way to acquire knowledge,
ıdertook many long trips. The most
ıportant was his visit to Kashmir.
More than any other person. Syed
i may be said to be responsible for
rning the eyes of Kashmir westward
the Islamic cultural centers of Per-
ı. Shawl weaving—the word Kash-
ir (cashmere) has since become a
word for quality woolen goods—
ıs possibly introduced by him. It was
this period that some of the other
ts and crafts that today make Kash-
ir the delight of tourists (papier-
âché and decorative metal work, for
ample) were also introduced. It
ems likely that they came from Tam-
lane's capital, Samarkand. Since
ımerlane was then importing arti-
ns from Damascus, it is hard to es-
pe the conclusion that some of these
ınsposed Arab craftsmen, or their
ns, may have gone on to Kashmir.

YED ALI's first trip to Kashmir was
in A.D. 1372. After a stay of a few
onths, he returned to Persia. He came
ain in 1379 and 1382, each time
ying more than a year, then going

home via Turkestan. This latter fact is significant in relation to Baltistan and the date of its conversion to Islam. The customary route to Turkestan from Kashmir was through Ladakh and over the Karakoram Pass. Baltistan has passes to Turkestan, but these are generally higher and more difficult to traverse, and have been long unused. Furthermore, in published records of Syed Ali's life and journeys, there is no mention of his having visited Baltistan. Yet the Balti have innumerable stories and legends about places Syed Ali visited, miraculous feats he performed, and mosques he built. In addition, there are natural features with which his name is associated, such as "the place where Syed Ali rested his walking stick," and "the place where Syed Ali stuck the arrows in the cliff." Some of these—the latter example, in particular—are confused with places associated with Kesar.

Since the next important Moslem figure does not appear on the scene in Baltistan for another century and a quarter (*ca.* A.D. 1505), I thought it might be possible to find out the exact route or routes taken by Syed Ali on his alleged visit or visits to Baltistan. Therefore, over the last three years, I have questioned the literate Moslems—mullahs, rajas, teachers—and other Balti on the point. The results are mystifying. In every valley it seems there is a tradition of Syed Ali's having come that way. Of the tales told by the many people with whom I spoke, hardly any two were the same. So the question of Syed Ali's presence in Baltistan remains open—probably answerable only through detailed examination of his own writings or those of his contemporaries regarding his travels.

THE later history of Baltistan is a record of the growth of sects, petty wars with the Ladakhis and the Kashmiris, subjugation by the Mongols of Turkestan and later by the Moguls of India, the coming of the British to India and the attendant return of Kashmir to the Hindus and, finally, in 1947, the reconquest of northern Kashmir and Baltistan by Moslem soldiers. This resulted ultimately in the current administration of Baltistan by the recently created Moslem state of Pakistan.

Among the key events of this period was the arrival in Kashmir—and subsequent banishment to Baltistan in A.D. 1505—of the Persian envoy and Sufi missionary Mir Shamsuddin Iraqi. Next to Syed Ali Hamadani, he is the best-known Moslem figure of Baltistan. It was apparently he who popularized a new sect, the Nur Bakshiya, that purported to present a *middle road* between the major Islamic schools, the Sunni and the Shiah. At one time this sect comprised the entire population of Baltistan. Its origins are shrouded in mystery, for it was persecuted and banned in Persia during the early years of the sixteenth cen-

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MR. HURLEY, now a student at the University of London's School of Oriental and African Studies, has visited Baltistan five times. His first four visits were made while he was stationed in Pakistan with the United States Foreign Service.

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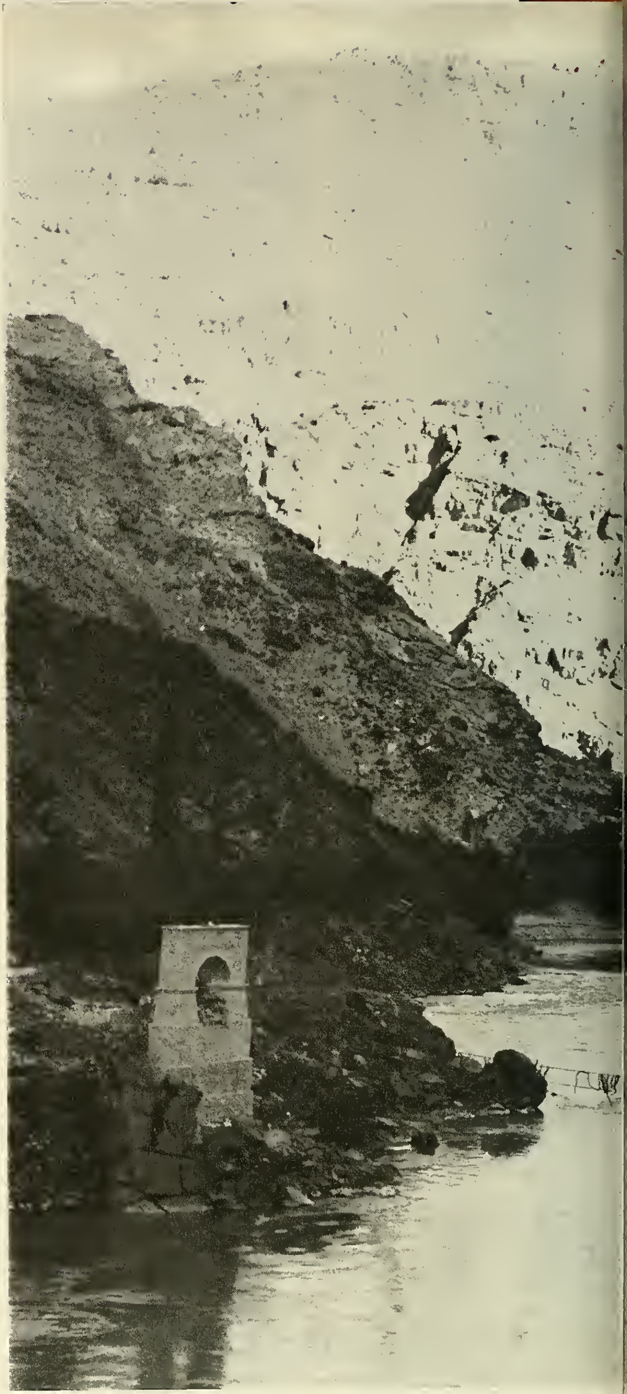
tury, and its remaining adherents have been incognito ever since. Indeed, the Nur Bakshiya sect exists now as a functioning body only in Baltistan.

ANOTHER interesting figure of sixteenth-century Baltistan was Ali Mir, the Raja of Khapalu. By his exploits and energy, he may be said to be the greatest lay figure in Baltistan's history. During the latter part of the sixteenth century, Ali Mir dominated not only all of his own country (which, both before and after him, had usually been divided up among rival petty rajas), but he also exercised suzerainty over what is now Ladakh, or Indian Tibet. Ali Mir's importance may be judged from the fact that he married one of his daughters to the Mogul Prince and later Emperor Jehangir—no mean accomplishment for a mountain chieftain. Another of Ali Mir's daughters was married to the King of Ladakh. From this union came two subsequent rulers, Sengge Namgyal and Deldan Namgyal, who were destined to lead diminutive Ladakh to the pinnacle of its power and influence.

IT is evident from the variety of national strains mentioned here that no simple answer to Balti racial origins is possible. But research on this question has been going on for the last 100 years and some progress has been made. To summarize the findings briefly: from the early idea that the Balti were primarily of Mongoloid extraction, the Austrian Baron Ujfalvy's expedition and researches of the late 1870's pushed the pendulum to the other extreme, saying they were almost entirely Caucasoid. The measurements made by the Italian professor Giotto Danielli in 1914 counteracted this, showing a strong admixture of Mongoloid characteristics in certain areas. Now, English scientists—using the newer method of blood type comparison—promise to shed further light on this vexing but fascinating problem: they hint at correlations with the Kirghiz and Uzbeks of western Turkestan, which is now considered a part of Soviet Central Asia.

(To be concluded in November)



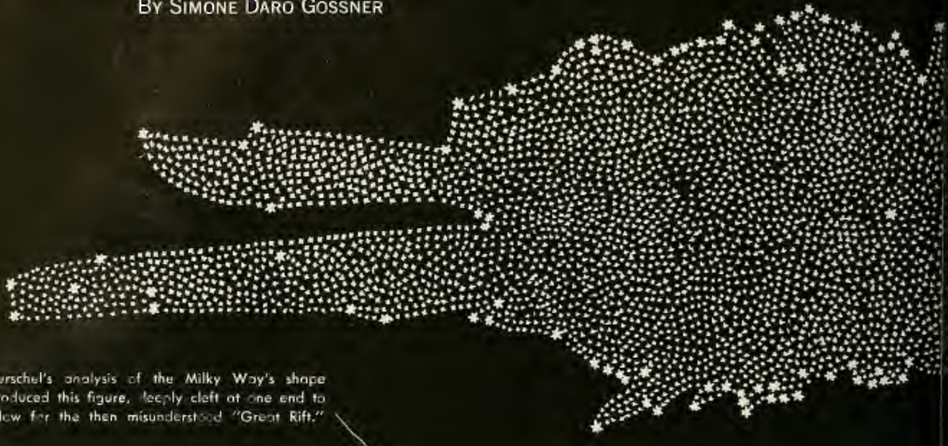
ROPE BRIDGE crosses the Indus Riv
near Kharmang. The promontory, rigl

f center, is the site of the ancient
ortress-castle of the Raja of Kharmang.

SKY REPORTER

Herschel and the Galaxy's structure

By Simone Daro Gossner



Herschel's analysis of the Milky Way's shape produced this figure, deeply cleft at one end to allow for the then misunderstood "Great Rift."

A substantial advance in the discovery of the universe could logically have been expected from the invention of the reflecting telescope: the skill and indomitable spirit of William Herschel transformed this advance into the most spectacular forward leap in the history of astronomy.

German-born (at Hanover, in 1738) and raised to be a musician, Herschel left his war-torn country at the age of 19 to seek a career in England, where he eventually secured the post of concert director at the fashionable resort of Bath. Although his interest in astronomy had been little more than a hobby at first, Herschel found himself increasingly absorbed in the subject until, in 1782, he resigned his post to devote all his time to scientific pursuits.

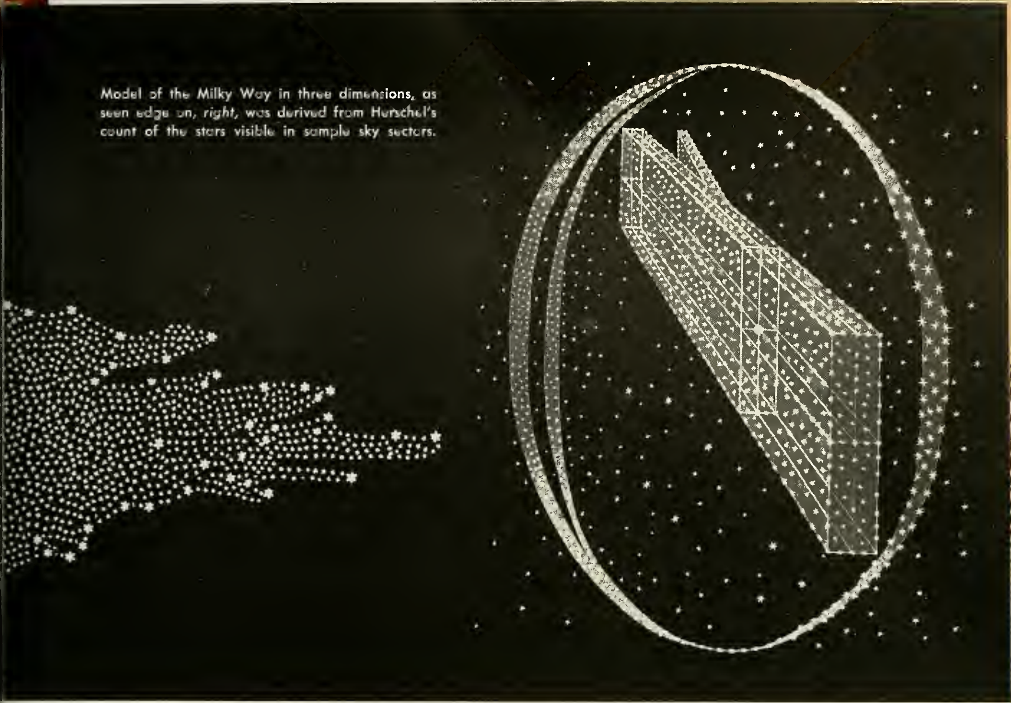
By then, Herschel had already acquired an international reputation for his discovery, in 1781, of the planet Uranus. His principal interest, however, was concerned with the study of stars and other celestial objects outside the solar system. To that end he designed—and built in his own workshop—a number of telescopes of ever-increasing size. It must be remembered that, in astronomy, the magnification of a telescope is secondary to its light-gathering power, for the latter is proportional to the area of the mirror and governs the amount of light that is concentrated into a star's reflected image. Therefore a larger telescope allows one to see fainter stars, and thus, on the average, permits the observer to penetrate deeper into space.

With his superior instruments, Herschel undertook systematic studies on every conceivable astronomical subject —on planets and satellites in the solar system, on the nature of the sun, on the motion of the sun in space, and on double and variable stars. His major contribution to cosmology, however, came from his efforts to ascertain what he termed "the construction of the heavens."

Until Herschel's time, stars had been treated as so man pinpoints of light inside a hollow sphere and as convenier reference marks for orientation. Little thought had bee given to their distribution in depth. Intrigued by the a pearance of the Milky Way, which he saw as a brilliar band of faint stars girding the celestial sphere, Hersch explained its appearance as an optical illusion created b an effect of perspective. He pointed out that if stars, i cluding the sun, are distributed in a relatively thin stratu or layer, an observer would see a great condensation stars in all directions within the stratum's plane, but onl a few scattered ones at right angle to it. The result woul be, of course, a narrow circular band of stars in the sk He even assumed that the layer was forked at one end, i order to explain the so-called "Great Rift of the Milk Way" in the constellation Cygnus (see diagram at lef *above*). We know now that the Rift is caused by th interposition of a dark nebula, but the existence of no luminous clouds in space is a modern concept.

The next task was to determine, if possible, the gener shape of the stratum. For that purpose, Herschel intr duced a sampling system, which he called "star gauges His procedure consisted in sweeping small sections of t sky and performing an actual count of the number of sta in the field of view of his telescope. Considering that one instance he found as many as 588 stars in a field abo one quarter the size of the full moon, and that he extend his sweeps over the entire sky, one may well imagine t enormous extent of this undertaking.

By using his star gauges, Herschel acquired a rough id of the three-dimensional shape of the Milky Way. As working hypothesis, he assumed at first that stars a evenly distributed within the volume of our Galaxy; th



Model of the Milky Way in three dimensions, as seen edge on, *right*, was derived from Herschel's count of the stars visible in sample sky sectors.

ie number of stars counted in a given gauge could be in-
erpreted as a measure of the distance to which the Galaxy xtends in that direction. A comparison of his star counts i various parts of the sky led him to the sketch (diagram t right. *above)* of our disk-shaped stellar system as the itter would appear to an edge-on viewer.

In reality. stars are often found in clusters. and it cannot e said that they are evenly distributed. On the other hand, ainter stars. *on the average*, are also farther away: thus ney are more numerous than the brighter ones in a given rea of the sky. because they represent a greater volume f space. As a consequence, Herschel's results did not ray far from a true picture of the system.

MUCH of Herschel's career was spent refining these views on the structure of the universe. Many of the bjects that he had first seen as small. nebulous patches ecame clusters of faint stars when he observed them again ith larger telescopes. So confident was he in the power f his instruments that he assumed. sooner or later. he ould be able to resolve all nebulae into star clusters. his was not to be. of course. since many of these objects re indeed diffuse masses of luminous gas. Herschel him-elf established this fact by simple reasoning when he ter found a star surrounded by a ring of nebulosity.

The fact that light does not travel instantaneously had een known for about a century when Herschel discussed is observations of nebulae and clusters. He used this roperty to point out a phenomenon. which has become miliar to the modern astronomer; namely. that one does ot see a distant star as it is now. but as it was when the ght rays left it. Applying this fact to his own research. he lassified all nebular objects in decreasing order of brightness and assumed that he had obtained in this manner an evolutionary sequence, the fainter objects being also the younger. Later investigations did not confirm his results because he was unable to distinguish the various categories of nebulae and clusters, but the principle of associating increasing distance with lesser age is now a classical method in the study of the evolution of galaxies.

It is worth noting that, from a theoretical standpoint. Herschel's concepts on the structure of the Galaxy and the nature of nebulae and clusters were not original. A few decades earlier, the Englishman Halley had pointed out that some of the nebulae seemed too large to draw their illumination from the faint stars observed within them, and must therefore be self-luminous. In France, Pierre de Maupertuis, doubting that all nebulae could be resolved into stars, concluded that they must be amorphous masses much larger than individual stars, since one can observe their outline in spite of their great distances.

Finally. Immanuel Kant. in Germany, proposed the correct explanation of the appearance of the Milky Way and assumed that other "island universes." similar to our Galaxy, might also exist. But in most cases—contrary to Herschel's approach—these theories resulted from speculations ranging far beyond the meager data available.

Toward the end of his career, Herschel said once "I have looked farther into space than ever human being did before me." Yet his greatest achievement lies not so much in that —an adroit gadgeteer, with a suitable urge, could have built just as large or a larger telescope—but in Herschel's extraordinary ability to interpret his observations. Little was added to the concertmaster-cosmologist's discoveries until the development of spectroscopy and the invention of photography opened up the modern era of astronomy.

THE SKY IN OCTOBER

From the Almanac:

Last Quarter	October 1, 9:10 A.M., EST
New Moon	October 9, 1:53 P.M., EST
First Quarter	October 16, 11:35 P.M., EST
Full Moon	October 23, 4:31 P.M., EST
Last Quarter	October 31, 3:59 A.M., EST

For the visual observer:

Mercury, in Virgo, will be poorly placed for observation, except for a few days at the end of October. Setting a scant forty-five minutes after the sun on October 1, it will be at inferior conjunction on October 22 and will enter the morning sky on that date. By October 31, it will rise about an hour before the sun. Its magnitude will brighten rapidly in the last few days of the month, from +1.5 on October 28 to +0.7 on October 31.

Venus (−3.4 magnitude) will be a morning star all month, rising at 3:30 A.M., local standard time, on October 1, at 4:00 A.M. on October 15, and at 4:30 A.M. on October 31. It will be visible in the eastern sky before sunrise.

Mars (magnitude +1.8) will set in the west about thirty minutes after sunset throughout the month of October. It will be too close to the sun for observation.

Jupiter (−1.9 magnitude), in the constellation Capricornus, will be low in the southern sky at dusk, setting in the southwest at midnight on October 1, at 11:15 P.M. on October 15, and at 10:30 P.M. on October 31.

Saturn (+0.8 magnitude), in Sagittarius, will be about 5° west of Jupiter. Thus it will precede that planet by about twenty minutes during October.

Observation of the Orionid meteor shower, on October 20, will be hampered this year by a bright, gibbous moon. Under more favorable circumstances, as many as twenty-five meteors per hour might be seen by a single observer.

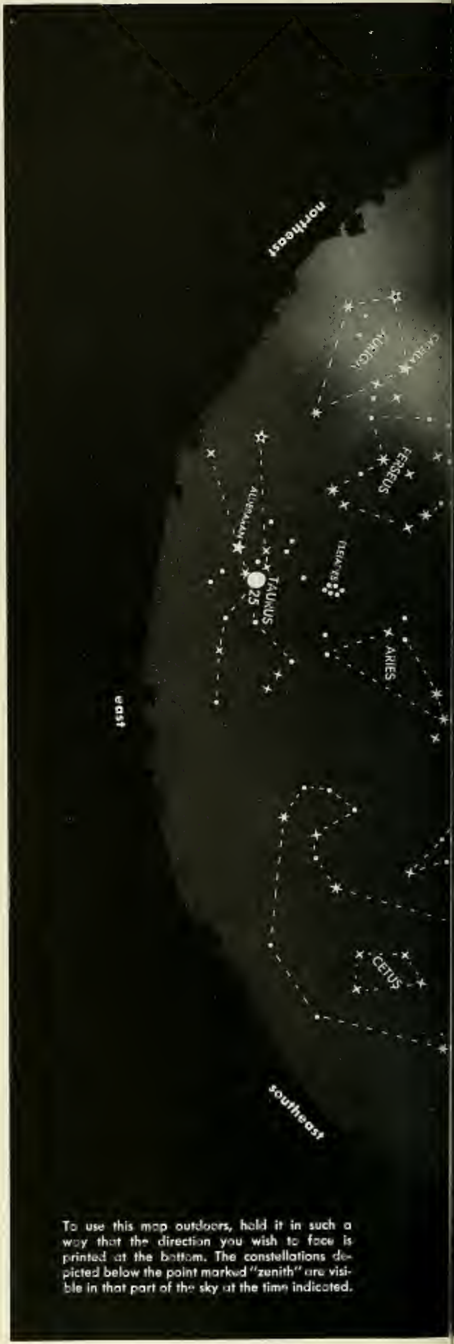
Morning and evening stars:

According to the astronomical definition, a planet is said to be in the evening or in the morning sky if it crosses the local meridian before or after midnight, respectively. Although this definition holds true for all planets, it is simpler, in the case of Mercury and Venus, to say that they are in the morning sky if they rise before the sun, and in the evening sky if they set after the sun.

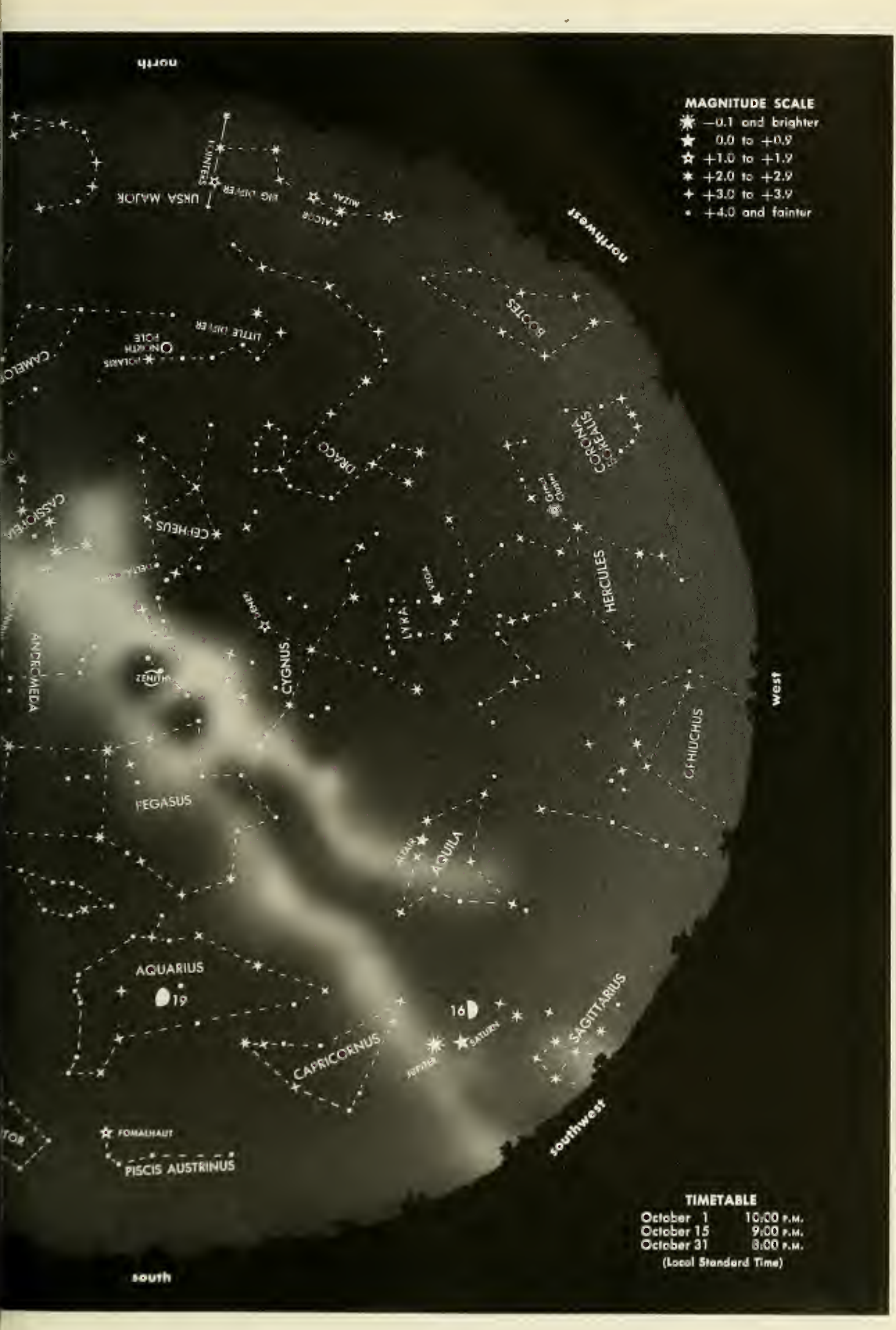
The expressions *morning* and *evening stars* reflect a traditional usage, which dates back to ancient times, when planets were believed to be "errant stars." To this day, in popular lore, these terms have been applied almost exclusively to Mercury and Venus—particularly the latter.

The astronomers of ancient Greece were well acquainted with the fact that Venus could be seen both in the evening and the morning sky, and recognized it in both instances. But the Greek poets, on the other hand, were accustomed to calling the morning star "Phosphoros" and the evening star "Hesperus," without regard for their being two aspects of the same celestial body. Rather than being mere poetic license, these names must owe their origin to the beliefs of yet earlier times, when men were fully convinced that Hesperus and Phosphoros were different bodies. Only in these ancient days did the expressions *morning* and *evening star* have any logical meaning: they have been nothing but misnomers ever since.

On the preceding pages, MRS. GOSSNER offers the eighth in her 1961 series on the growth of cosmological concepts.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.


north
URSA MAJOR
POINTERS
BIG DIPPER
MIZAR
ALCOR
northwest
MAGNITUDE SCALE
✹ −0.1 and brighter
★ 0.0 to +0.9
☆ +1.0 to +1.9
✱ +2.0 to +2.9
✦ +3.0 to +3.9
• +4.0 and fainter
BOOTES
LITTLE DIPPER
NORTH POLE
POLARIS
CAMELO
DRACO
CORONA BOREALIS
Great Cluster
CASSIOPEIA
CEPHEUS
DENEB
VEGA
LYRA
HERCULES
CYGNUS
ANDROMEDA
ZENITH
west
OPHIUCHUS
PEGASUS
ALTAIR
AQUILA
AQUARIUS
19
16
SAGITTARIUS
CAPRICORNUS
JUPITER
SATURN
southwest
TOR
FOMALHAUT
PISCIS AUSTRINUS
south

TIMETABLE

October 1 10:00 P.M.
October 15 9:00 P.M.
October 31 8:00 P.M.
(Local Standard Time)

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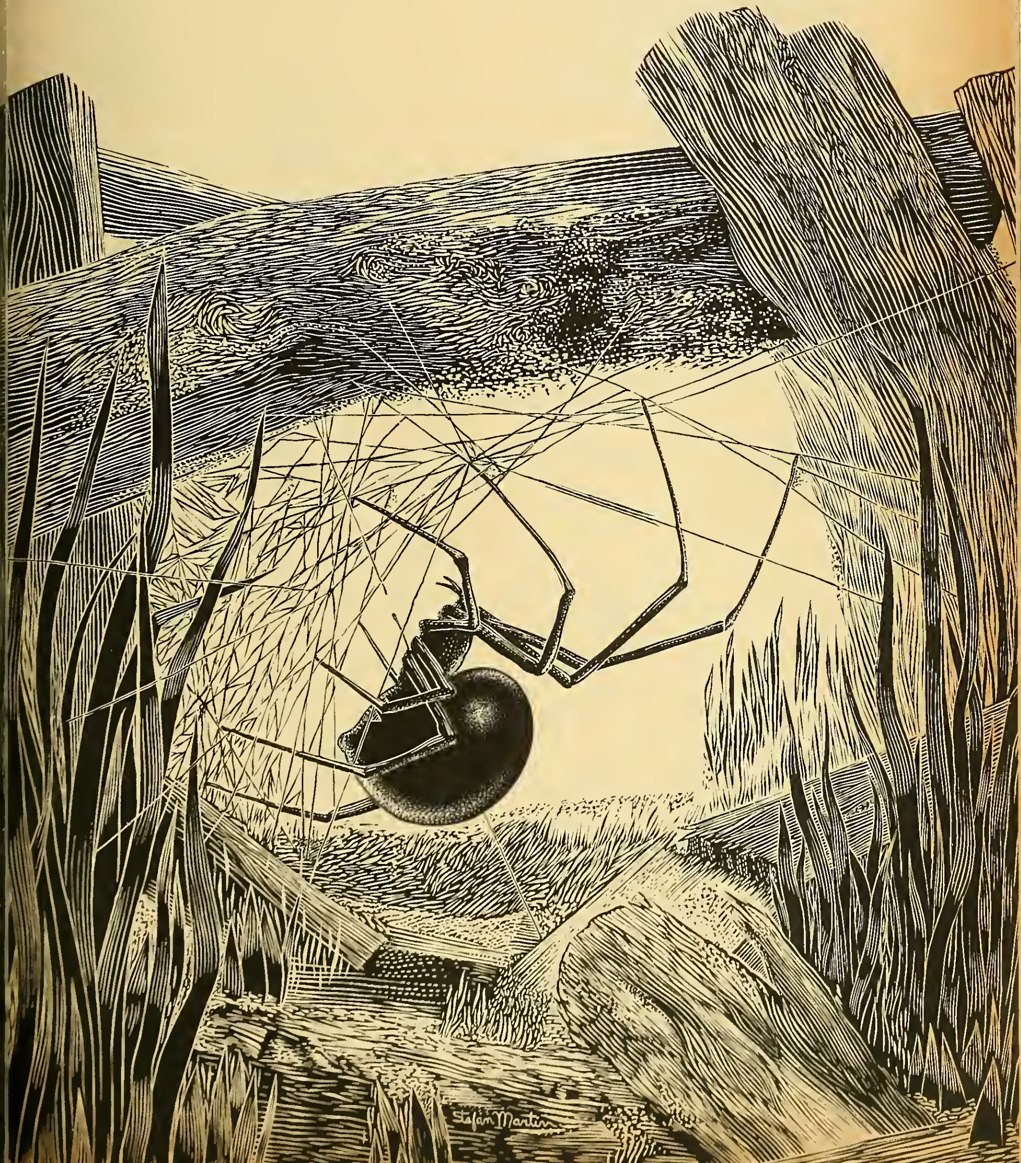
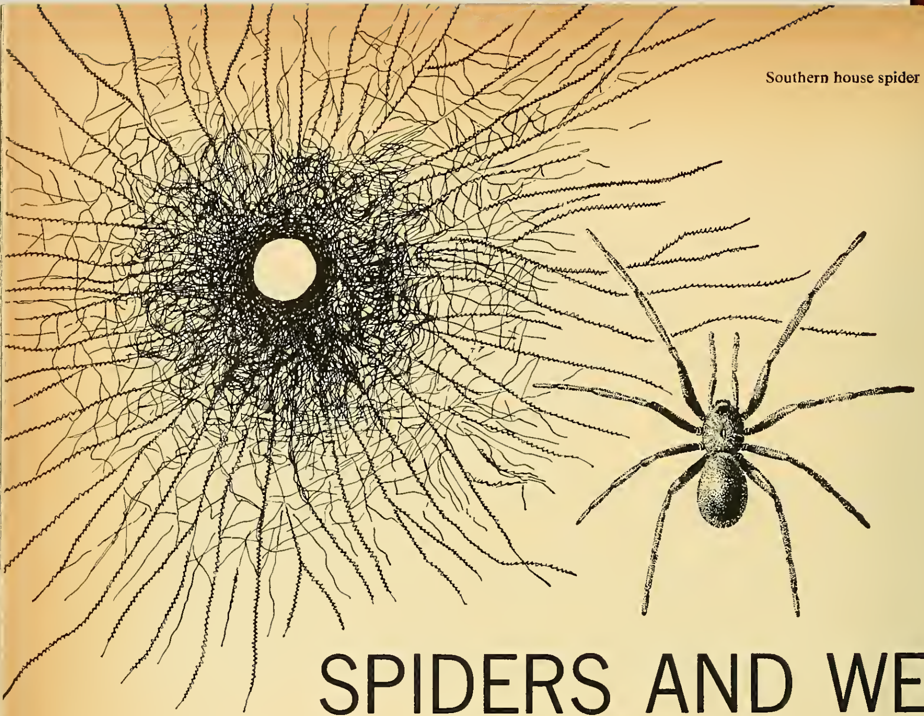

Stefan Martin



Southern house spider

SPIDERS AND WEBS

Various types of spider webs afford rich area of special stud

By E. Laurence Palme

There must be few of us, indeed, who at one time or another, have never seen, touched, or perhaps experimented with spiders and their webs, the subjects of this educational insert. These animals and their gossamer creations may be secured at any time of the year, and they furnish study material that costs nothing. There are few zoological subjects about which there is more misunderstanding, and it is difficult to find simple information about them in printed sources. It is the webs that will be emphasized in this insert.

In size, certain spider webs may measure up to several feet in width. They may be constructed with a marvelous engineering skill, and are designed to assist in the protection, food-getting, transportation, and other affairs of their makers. Their study can afford pleasure, wonder, and a challenge, and prove well worth the necessary time and effort. We must consider the nature of the materials used by spiders in making their webs, and the source of those materials. We should be able to recognize the engineering aspects of spider webs, the functional part they play in the lives of spiders, and the role, if any, they have played in human affairs and literature.

Obviously, it should prove easier to find a four-foot spider web in the woods than to find its maker, whose body may measure less than an inch in length. If, therefore, the reader would like to know more about spiders, it might first be well for him to learn to recognize webs.

One-third of the spider webs considered in this inse
look like huge spoked wheels with spirals arranged o
the spokes. Two other types of webs are platforms, on
being found most commonly indoors, and the other mo
commonly outdoors. One spider builds a platform sup
ported above and below by strong stays, although th
web as a whole has only a vague design. Two spide
build webs that are irregular open nets, commonl
placed over an opening in a wall, or under a log or roc
Two other spiders build delicate "bowls," one kind th
is right-side up, with a platform beneath it, and on
bottom-side up, but so porous that captured insects ma
be pulled through it by its maker, who hides beneath.

One species of spider builds a web only as a cov
for the nursery in which its young are confined an
guarded. However, most of the webs discussed in th
article are traps of one sort or another; and it should
added here that there are about as many types of we
as there are of spiders. Correlatively, a spider may te
tatively be identified by the kind of web it makes, an
closely related spiders make webs that resemble or
another to a greater or lesser degree.

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There are many types of webs that cannot be discussed here. There are also many spiders that do not make webs of a conspicuous nature; some make webs only for special purposes or at special times.

There are few places where active spiders may not be found at some time of the year. Certain spiders may even live—although they do not build their webs—in the snow. Of the spiders listed in the chart section of this insert, the southern house spider, *Ariadna,* the squint-eye spider, the domestic platform spider, the black widow spider, the house spider, and some of the members of the family Araneidae are most likely to be found in houses and barns. Meadows and lawns are favored by grass spiders, which build nets with trip-threads stretched above them in the grass. The trip-threads are designed to upset insects so that they fall into the net, to be captured and eaten. Woodlands are the habitat of triangle spiders and the filmy dome spiders, while the vicinity of waterways is likely to be favored by the long-jawed orb-weavers, fishing spiders, and others. Some water spiders are able to walk on the surface of water, while others can dive below the surface to capture the animals upon which they subsist. These latter may even carry a supply of air with them for use in their submarine pursuits.

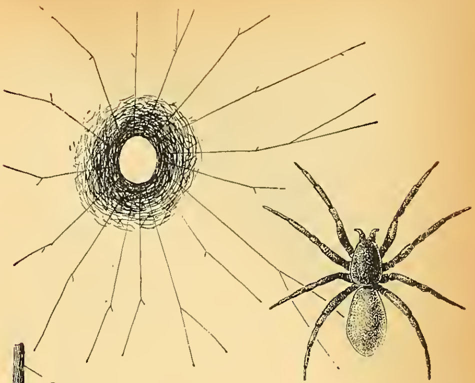
TEMPERATURE may affect the activity of some spiders, but in general the animals prefer temperatures that humans find pleasant. To determine the temperatures at which spiders are most active, put one in a deep glass container, such as an empty olive bottle. Put a thermometer in the bottle, and pack cotton into the bottle's throat, so that the spider cannot escape. Move it from the refrigerator to a warm oven, first determining the room temperature. This will give the temperature range at which the spider is most active.

Spiders have rather definite light preferences. Some species favor darkness, and others light. Many may begin to move when the light fades, and their activities must then be observed with the aid of a flashlight. Much of the construction and repairing of webs takes place during the hours of darkness.

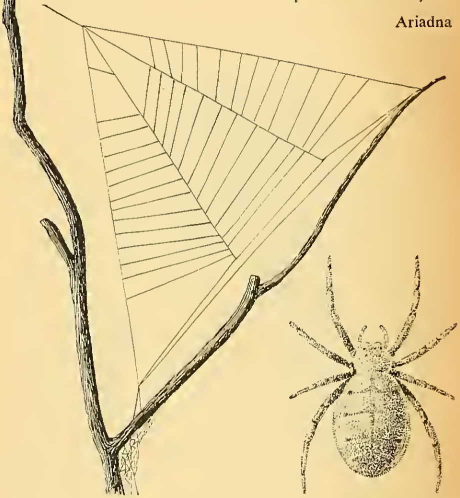
Rain, fog, and dew may affect the webs of some spiders by adding weight to an already well-taxed and flimsy structure. Many spiders select sheltered, dry locations for their webs, a circumstance that indicates their attitude toward water. However, spiders must have access to a certain amount of water to stay alive, and if specimens are being kept captive for observation, it is well to dampen cloth, cotton, or blotting paper and put it where it may be visited by the animal. Spiders can usually survive starvation better than desiccation.

The food of most spiders is animal matter. However, few attack large animals, and apparently prefer to eat smaller prey, such as the insects that are snared in their nets. Some spiders have been known to exist for months without food with no observable difficulty.

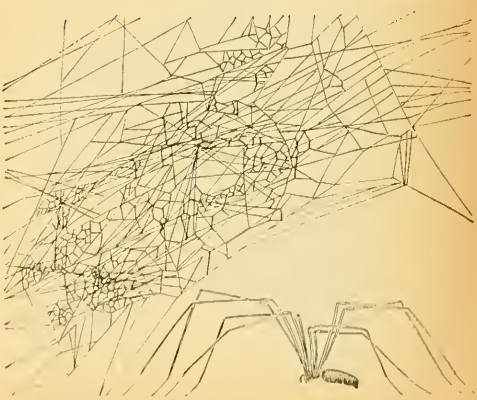
The bites of some spiders may be poisonous, but for the most part a spider bite is harmless. As far as a spider is concerned, its poison is most useful to quiet the struggles of a prospective meal. Spiders have many ways of capturing, quieting, storing, and eating their food; but these interesting activities cannot be considered here. Suffice it to say that a spider, detecting a captured in-



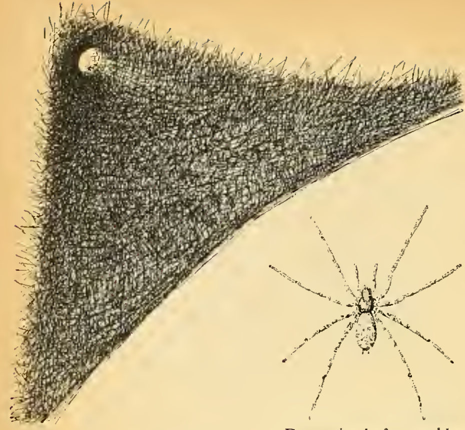
Ariadna



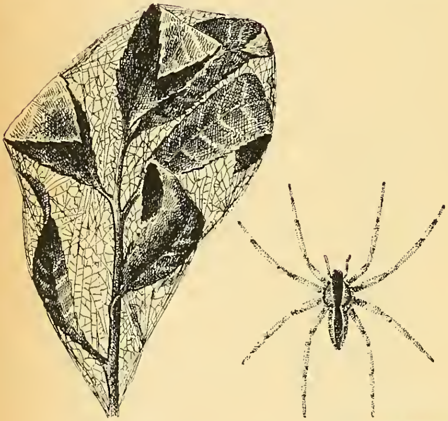
Triangle spider



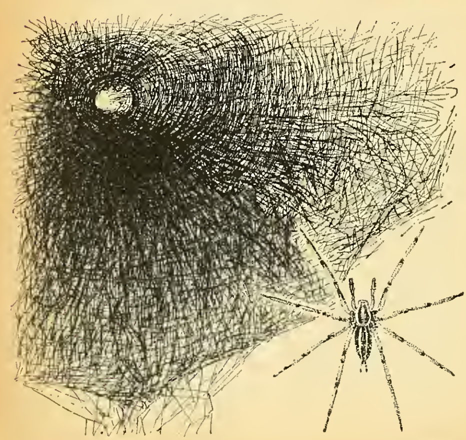
Squint-eye spider



Domestic platform spider



Fishing spider



Grass spider

sect, may come out on the web, bite the prey, throw some silk around it, and then return to its lair. If the prey continues to struggle, the spider will emerge, bite it again, throw more silk around it, and return to the lair.

Spiders are remarkable creatures of habit. Occasionally mammals as large as mice allow their tails to become entangled in a spider web. The spider goes through the routine outlined above, each time strengthening the attachment to the mouse and giving it a pull. In this way mice, snakes, and other relatively large animals have been captured and killed by diminutive spiders. With a little concentrated observation, the habit pattern of almost any spider may be easily investigated.

Some spiders are sensitive to certain noises. Often a spider will drop from its web to the ground when a certain musical note is sounded, and different notes affect different kinds of spiders. Some most interesting studies of the reactions of spiders to sound have been made at Harvard University.

The general life history of spiders is well worth learning. For most spiders, life begins in a silk egg cocoon that is crowded with eggs. This mass of eggs is almost always protected in some way from the elements. Hatching temperatures are variable; some of the beautiful orb-weaver spiders of our summer gardens were hatched from their eggs in a weed-top cocoon in the coldest part of the year. Other species may hatch at almost any temperature at which life can exist.

Since spiderlings find themselves crowded together in a cocoon with no special food stored away for them, they merely wait until another egg hatches and then eat a helpless brother or sister. This continues until the more aggressive spiderlings free themselves from the cocoon. From the beginning, a spider's life is a hard one; but obviously the survival rate is sufficient.

Once free of the cocoon, the young spider faces an uncertain future. Some youngsters may cling to the backs of their mothers, and thus be carried about. They may spend some time in a silken nursery, protected by the watching mother. They may move about on the web made by the adult, and feed on food scraps found there. Or they may begin to shift for themselves at once, without ever having seen their parents.

As small spiders move about and secure food, they increase in size. Since their skeletons are on the outside, they cannot gain flesh; when they grow they must shed the exoskeleton and develop a newer and larger one. This process continues at least until the animals are mature. Mature males are usually much smaller than females, and the lack of equality between the sexes is noteworthy. Sometimes a courting male is not welcomed by a prospective mate, and she may eat him. In some species the female eats the male after mating. It is not necessary for mating to take place prior to each egg-laying, since the fertility of the female may continue for some time. A spider may live for a number of years.

Reproduction is one phase of a spider's life; securing food is another. A spider must eat and at the same time avoid being eaten. To understand something of the intricacies of food-getting, let us consider the unwelcome fly that buzzes about your house. You do not want it there, but some spider wants it for a meal, and has various means by which to capture it.

Basic to all spider webs is spider silk, one of the most remarkable substances to be found in nature. (There are some spiders that make little use of silk, but they will not be considered in this insert.) In the spiders dealt with here, silk is ordinarily produced by one or more of seven different types of glands. Usually these glands have shapes that have given them their names, and each may have a special function. Some may be limited to spiders belonging to particular families; also, some spiders have more kinds of glands than others.

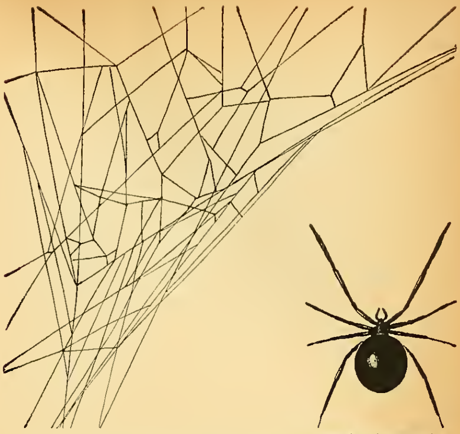
Among the silk glands found in spiders are those that are berry-shaped, those that are pear-shaped, and others that are bellied, cylindrical, tree-formed, or lobed. The berry-shaped glands are to be found almost universally. They produce a silken swathing band useful for binding a victim quickly, and may feed into middle or rear spinning tubes, which may number from a few to hundreds. There may be four clusters of such glands, having from a few to many glands to the cluster.

The pear-shaped glands are also found in many groups of spiders. They are in two clusters, each with from one to many glands that feed spinning tubes whose openings are in front of those of the berry-shaped glands. The silk from these glands serves in the production of attachment discs for the strands of silk. A series of four-, six-, eight-, or twelve-bellied silk glands is generally found on the silk producers, except in the hindmost spinning tubes. These glands produce the great draglines and the dry threads of the webs. They may also be responsible for the production of elastic silk, some of which can be stretched up to fifty times its original length. These glands, like the others mentioned, are common in most silk-producing spiders.

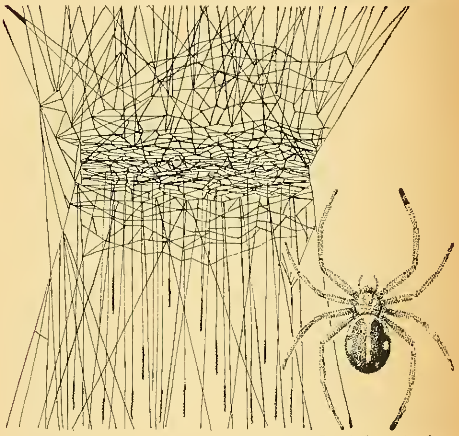
SOME silk glands are more specific than those mentioned so far. There are, for example, sets of certain cylindrical glands that may number up to six or more in a female, and fewer—or none at all—in the male. These, like the bellied glands, open through spigot ubes. Since they produce the silk used in making the gg sac, they are not necessary to the males, which do ot produce such a sac. They are also absent in a few amilies not included in the list covered in the chart secion of this insert. The cylindrical glands open on the middle and rear spinning tubes.

Tree-form tubes—four large and two small—open nto the rear spinning tubes. They have pointed tips, indicating the need of specific placement, and produce he particularly sticky drops needed by members of the Theridiidae, the Linyphiidae, and the orb-weavers. The wathing film that is characteristic of spiders related to he house spiders—and which the animals throw over a rospective meal—is produced by two- or four-lobed glands that feed one or two spinning tubes near the rear. These glands feed through a spigot-like tube.

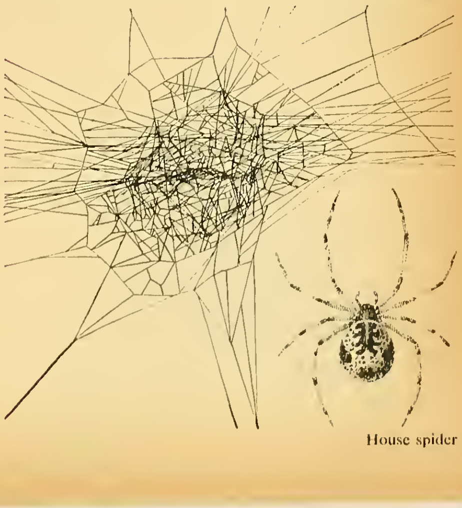
Some of the silk in the webs of the first two species onsidered in the accompanying chart section has a laceike appearance because of the presence of a series of ine loops spread on more substantial strands. To help n the production of this type of silk, another gland may e found in a few species of spiders. This is called the ribellum, and it opens on the underside of the body orward of the other glands described. With the silk from hese seven types of glands, spiders can travel, eat, pro-



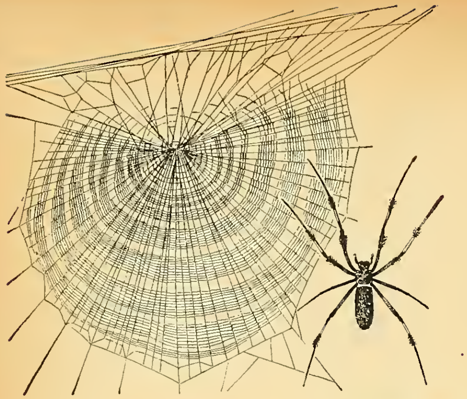
Black widow spider



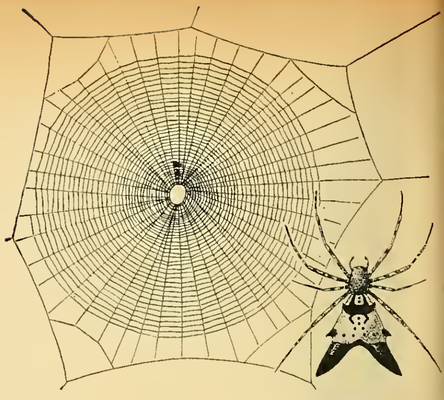
Comb-footed spider



House spider



Golden-silk spider



Arrow-shaped micrathen

tect themselves, communicate, protect their young, and meet the important problems of a spider's life.

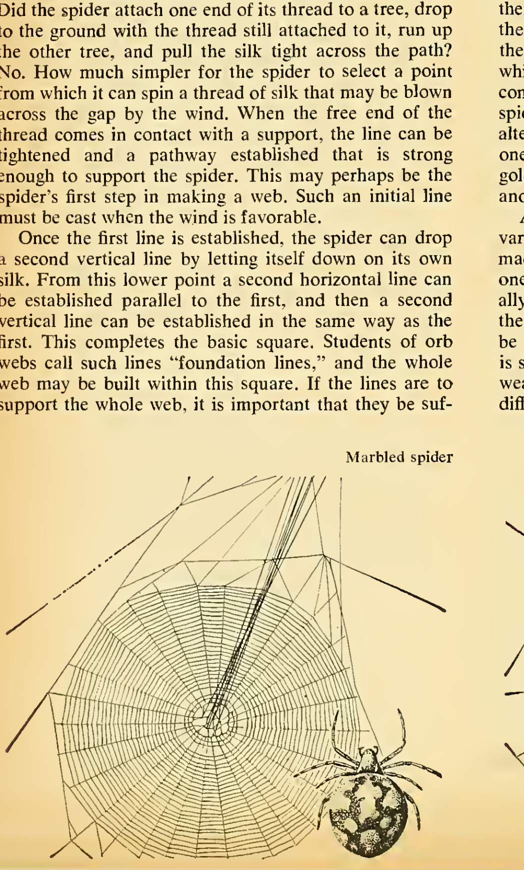
A walk down a woodsy path in summer will almost certainly bring you into contact with a strand of silk, stretched across the path from one tree or tall plant to another. You may wonder how it could be placed there. Did the spider attach one end of its thread to a tree, drop to the ground with the thread still attached to it, run up the other tree, and pull the silk tight across the path? No. How much simpler for the spider to select a point from which it can spin a thread of silk that may be blown across the gap by the wind. When the free end of the thread comes in contact with a support, the line can be tightened and a pathway established that is strong enough to support the spider. This may perhaps be the spider's first step in making a web. Such an initial line must be cast when the wind is favorable.

Once the first line is established, the spider can drop a second vertical line by letting itself down on its own silk. From this lower point a second horizontal line can be established parallel to the first, and then a second vertical line can be established in the same way as the first. This completes the basic square. Students of orb webs call such lines "foundation lines," and the whole web may be built within this square. If the lines are to support the whole web, it is important that they be sufficiently substantial to stand the strain—and they are
Once the frame is established, the rays and spirals ma
be made with comparative ease. As a rule, the rays ar
not sticky; but some—and sometimes all—spirals are

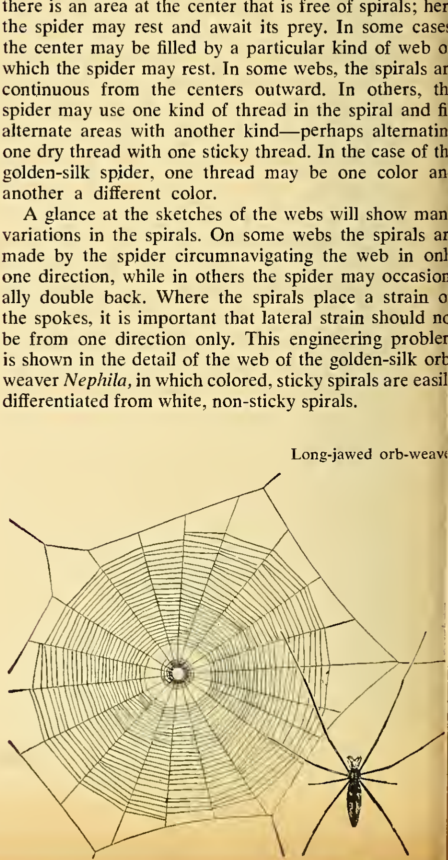
It may be noticed in the accompanying illustration
that the spirals are quite variable. In some instances
there is an area at the center that is free of spirals; her
the spider may rest and await its prey. In some cases
the center may be filled by a particular kind of web o
which the spider may rest. In some webs, the spirals ar
continuous from the centers outward. In others, th
spider may use one kind of thread in the spiral and fi
alternate areas with another kind—perhaps alternatin
one dry thread with one sticky thread. In the case of th
golden-silk spider, one thread may be one color an
another a different color.

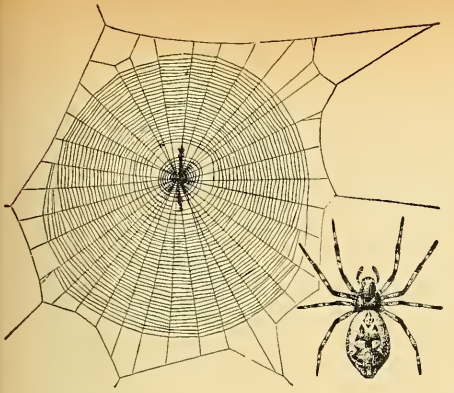
A glance at the sketches of the webs will show man
variations in the spirals. On some webs the spirals ar
made by the spider circumnavigating the web in onl
one direction, while in others the spider may occasion
ally double back. Where the spirals place a strain o
the spokes, it is important that lateral strain should n
be from one direction only. This engineering proble
is shown in the detail of the web of the golden-silk orb
weaver *Nephila,* in which colored, sticky spirals are easil
differentiated from white, non-sticky spirals.

Marbled spider

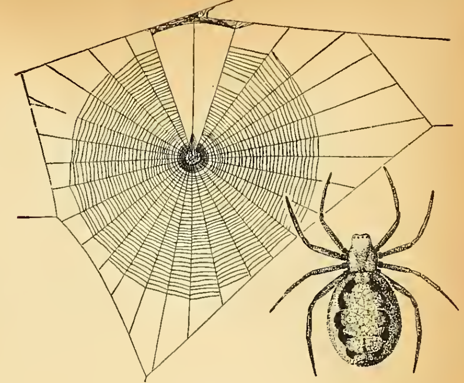


Long-jawed orb-weav





Cyclosa



Zygiella

In studying the webs of the orb-weavers in the genus *Micrathena,* and some others, it may be seen that some of the spokes are connected by a conspicuous unit of silk that the spider may shorten or lengthen, depending on whether the web must be loosened or stretched more tightly. This is the stabilimentum, and its placement in the web varies. It sometimes appears on both sides of the center, and sometimes on one side only.

The web of *Zygiella* merits special study. It will be noted that the spiral thread in this web fails to close the gap between two of the radii. Down that gap extends a strong line reaching from the hub of the web to a silken retreat, open at each end but placed out along the foundation line. In this case, the spider can rest in a retreat from which it can escape in either direction, and yet it has a communication line with the hub of the web, and can quickly reach a place in the web where a potential meal has been ensnared.

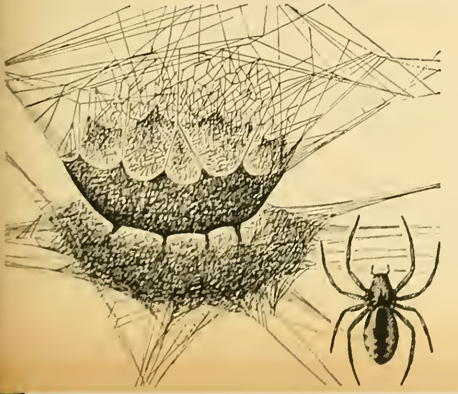
In *Araneus,* the web exhibits a variation of this arrangement. The spider is outside the original foundation lines, but is still connected by communication lines with the hub of the web. This arrangement guarantees the spider greater safety without lessening its awareness of any activities occurring on the web.

In *Tetragnatha,* there is an interesting variation of the orb web. While ordinarily the orb web is placed more-or-less vertically, in *Tetragnatha* it is commonly tipped over toward the horizontal. Since the web of this spider is commonly spread over running water, the horizontal position better serves to catch insects that are usually found in such places. Can any of the readers imagine why this should be the case?

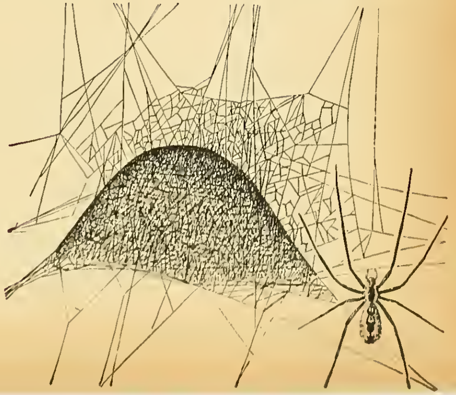
In studying the various webs, the student should not fail to notice the clever way in which *Ariadna* manages to keep its web free, even though it ordinarily lies close to a stone or other surface. He should also study the web of *Hyptiotes,* a splendid sort of trap in which the spider stands ready to shake its triangular sheet-web to entangle its prey in the sticky cross-threads. The exploration of an old barn or cellar will certainly reveal the loose, irregular web of a house spider, or that of *Pholcus.* If something is dropped into the web, the spider may come out and jump up and down in the web in great excitement. This is the way the spider manages to throw at least one thread around an intended prey.

The reader who studies spiders and their webs will doubtless marvel over the behavior patterns of these creatures, and their differences in anatomy and web construction. If he will read various books about spiders, he will find how spiders and their webs differ one from the other, and also how the authors differ in their interpretations of the phenomena they observe.

Bowl and doily spider



Filmy dome spider



	WEB	DESCRIPTION
Southern House Spider *Filistata hibernalis* Family Filistatidae	Silken sac larger than spider but smaller than retreat hole is suspended in retreat by radiating, paired threads to 6 inches or longer, extending to more than 6 inches from sac to a remote attachment. Threads may stretch to 50 times original length. They are covered with hackled loops and a sticky sheath.	Male pale tan, to 2/5 inch long. Female dark brown, with dusky patches on back and black fuzz beneath, to about 4/5 inches long. Over-all length to 2 inches. Legs stout. Eyes close together in one group. Legs about 2 times body length, with front pair the longest. Silk of 4 kinds in web, which soon dirties.
Ariadna *Ariadna bicolor* Family Segestriidae	Retreat hole slightly larger than spider is lined with long, slender, silken tube suspended by threads from retreat wall and bordered at mouth by silken collar. Many strong radiating threads are supported by 2 or more piers. Whole structure is sensitive to touch.	Male to under 1/3 inch long, with female under 2/5 inch long with long oval abdomen. Purplish brown above and below and paler sides give species "bicolor" name. Forward 3 pairs of legs directed ahead permit speedy emergence. Legs lighter than body.
Triangle Spider *Hyptiotes cavatus* Family Uloboridae	Web basically a 4-pronged fork suspended between dead twigs, with unusually long handle to keep web taut, and with 10 to 20 separately installed cross threads, connecting prongs—each doubled and with hackled bands—and sticky threads. Spider shakes web by agitating the handle.	Adult female to 1/6 inch long, male to 1/10 inch, resembling dead buds of tree — usually an evergreen — in twig crotch of which web is suspended. But for web, adults would be hard to find. Female's abdomen has double row of rounded bumps, which are much less developed in male.
Squint-Eye Spider, Pholcus *Pholcus phalangioides* Family Pholcidae	Webs to a number of feet in diameter, highly irregular, loose and open, in which spider hangs head or back down. Old webs heavily dust-laden. Web shaken violently by spider when potential prey becomes entangled, further trapping the animal. No egg cocoons are found hanging in web.	Male body to ¼ inch long, female to 1/3 inch. Abdomen length twice its width, with sides usually parallel and rear blunt. Slender legs, to 2 inches long, give animal appearance of daddy-long-legs. Body pale brown to straw-colored. Gray mark in center back. Leg joints contrast.
Grass Spider *Agelenopsis naevia* Family Agelenidae	Silken platform to 3 ft. or more across, basically of strong, nearly parallel threads from lower spinnerets that are crossed in all directions by a mesh of finer threads from upper spinnerets. Supported by grass or other objects. Retreat for the adult is in a rather short tube that hangs from one side of the net.	Male to 3/5 inch long, female to 4/5 inch. No great variation in length of pairs of legs. Color varies from light yellow with pale gray markings to dark reddish brown with black and gray spots or stripes. Often has conspicuous band down back. Leg joints are dark.
Domestic Platform Spider *Tegenaria domestica* Family Agelenidae	Densely woven layer of silk often broken by weight of dust and trash. Edge of web lower, higher, or on level of web body. Escape and hiding tube is at one side, close to the outside shelter. Commonly found in corners where they are not disturbed by animals, including one prime enemy, man.	Body of female to nearly ½ inch long, of male to 2/5 inch long. Legs give spiders over-all length to over 1 inch. First and 4th pair of legs about 2 times the body length, faintly banded and hairy. Light yellow-brown, with 2 gray, longitudinal stripes on body. Male abdomen smaller than that of the female's.
Fishing Spider *Pisaurina mira* Family Pisauridae	No snare web is built. Large nursery web a foot or more in diameter may be constructed, enclosing the whole top of a good-sized weed. This protects the hidden egg sac and emerging spiderlings during early days of their lives when they first become completely independent of cocoon.	Males and females almost the same size, with the slightly larger female 3/5 inches long. Yellow to light-brown with a dark-brown, broad, median band on the back. Abdomen is margined with white. Median area around eyes as long as its rear width. Some varietal differences within the species.
Black Widow Spider *Latrodectus mactans* Family Theridiidae	Web irregularly spread net with funnel-shaped retreat area, usually placed in protected spot. Often or frequently placed over opening through which prospective prey might be expected to pass. Web not elaborately zoned for particular purposes, as are other web types.	Female body to 2/5 inch long, male to 1/5 inch. Female shiny black with red spots and usually the familiar red hourglass mark beneath abdomen, but this may be reduced and varied greatly, or spots may be entirely absent. Spider hangs feet upward in web. Male may have white lines on sides of abdomen.
Comb-Footed Spider *Steatoda borealis* Family Theridiidae	Web a rather loose, open, well-defined platform, held by threads running to supports above and below the platform. In some cavities these supports may extend in almost any direction, giving the platform reasonable stability that is not continuous, as in *Tegenaria*.	Female to over ¼ inch; male slightly smaller. Back orange-brown, covered with short, stiff hairs. Abdomen chocolate-brown. Light median band on abdomen branches to form lateral band at forepart of the abdomen. Legs hairy and brown, often with faint dark rings.

ECOLOGY	RANGE	ECONOMY
Larger webs usually domains of females. Males may wander away on own or build smaller webs for catching food. Old webs may be over 1 foot in diameter, are sensitive to disturbances and warn adult in retreat of danger or trapped prey. Finely looped radii are lacy.	A common southern house spider that may be much at home under stones in fields, on or under surface of loose bark, on old wooden fences, or in stone walls. Is sedentary and not commonly seen unless sought. Range is through the southern states and west through California to West Coast.	Of no recognized major economic importance to man or to his stock or crops, but must destroy many insects of potential danger to man's economy. May adapt selves to artificial, wooden nest boxes and provide interesting indoor subjects for study on which little information has been published.
Webs found in and around holes in bark, rocks, weathered wood, and even under stones in fields. Females have been observed to remove exposed part of web in early July, then to lay about 15 eggs in spherical cluster, not enclosed in special egg sac, within retreat.	Range from New England to Florida and west through California in a great variety of habitats where suitable surfaces for retreats are available. Few places do not qualify for these conditions, but the penetrating holes must be long enough to provide protection and concealment for the spider hosts.	Probably of little direct economic importance to man, but does destroy insect pests. Interesting because of 3 pairs of forward-pointing legs that permit spider to throw self forward violently at first sign of prey. Lends self to artificial study environment.
Eggs deposited in flat, oval, silken sac close to bark of twig. Sac is about ¼ inch long, and according to Comstock appears under the microscope like dirty white silk crocheted with black silk. Camouflaging dirt makes the egg sac most difficult to find unless it has been deposited in vial by a captive female.	Ranges from New England to Georgia and west to the Pacific with related species extending range. To investigating naturalists, triangular web is not too uncommon, often being found on dead twigs of such trees as hemlock and pine. Finding adult spiders is ordinarily not an easy task.	Of no major importance to man, but there are few more interesting subjects for study than the manner in which this animal shakes its triangular web to entrap a meal, suddenly lengthening or shortening the handle of the prong that supports the crossbars of the web.
Egg cocoon transparent or straw-colored, with eggs visible. Cocoon with longest diameter under ½ that of body of female, who carries it about on web until young are freed. Almost invisible except under close examination. Young shift for themselves after being hatched.	Commonest American cellar spider, ranging through United States and into Europe, whence it was probably introduced. Found the year round, active in dark barns, cellars, and hidden areas where it is not disturbed. Becomes greatly excited by the presence of a potential meal when insect shakes web.	Of no great economic importance, but probably does serve as destroyer of flies that may seek secluded spots in which to winter. Not normally aggressive, and apparently is harmless to man and to man's domestic animals. Webs in cellars may be an annoyance.
Webs found most commonly in grass with a sparse maze of "trip threads" above platform. Threads upset flying insects, which fall to platform and are captured. Eggs, which hatch in winter, are in irregular flat silk sacs under rubbish, usually protected only by female.	Commonest of grass spiders, ranging from New England to Florida and west to Kansas and Texas (with related *A. pennsylvanica*), to Oregon and Washington. Not found in Southeast. White silk sac plano-convex, to 1/3 inch across. Common under bark, stones, piles of rubbish.	Valuable as destroyer of insect enemies of such field plants as grasses. Of no danger to man. Most fascinating subject for study at almost any time of year, but particularly from May through to winter. If food is available, is good subject for laboratory study.
Males and females live in unusual harmony on same web during the three months of the breeding season. Eggs are laid in oval, silken egg sacs, which sometimes remain suspended under the platform for a number of years. Adults may live two or more years, and be active at most times.	May be found under stones or in rock crevices, but is most common in barns and houses throughout the United States and parts of Europe. Platform-like web easily differentiated from loose, open, silky web of house spider. Food consists of insect material.	An essentially domestic species living on insects and other animal matter that becomes trapped in web. It is unpleasant looking and may mean household uncleanliness or neglect, but does not harm man, and may destroy insect pests. Provides fine subject for study.
Silken egg cocoon is in two halves, and is carried in special structures beneath the female's body until just before the young emerge. Then female builds huge silken web over top of some weed or other object, and in the web places the egg sac, which eventually opens to free the young.	Young may eat each other while in egg sac, but mother does not eat young. This may indicate there is some maternal care of the next generation. The young emerge in summer. Ranges from New England to Florida, southwest and west into Texas and Wisconsin.	Some relatives of this spider, including genus *Dolomedes*, which may live on, in, and near water, are reported to eat small fishes and aquatic insects. This can certainly not cause great injury to fish populations, and spiders themselves may be food for larger fishes.
In June or July, female makes 3-to-4¼-inch cocoons, each containing to 300 eggs that hatch into spiderlings. These feed on each other within the cocoon. Young may mature and breed by autumn, and the females may live through winter. Female commonly eats mate, giving name "black widow."	A retiring species, that attacks only in self-defense. There is no record of their having caused death of a healthy adult human. Common habitat is among stones or under rubbish and logs, where spiders may readily bite a hand thrust in to move the cover. Known in all the states but Maine, Alaska, and Hawaii.	Pain caused by bite is great and may cause paralysis of bowels. Ligatures properly and promptly applied may prevent spread of infection, and weak solution of ammonia and carbonate of potash may be applied with good results. Temperature of victim may be high for 3 days.
Sexes unusually alike in size and coloration. Males said to be able to produce high-pitched sound by use of stridulating organs. The purpose of this sound is not yet understood. In general, the animal resembles a short-legged house spider. Nest somewhat similar.	Not conspicuous, as it lives in crevices and corners under some cover of the nest or platform. This species ranges through the northern half of United States. Two other species are found in western part of the country. One, the commonest, is found in Canada.	Probably of minor importance to man and his interests, but it may destroy some harmful insects. The webs may help in the construction of some birds' nests, while the spiders themselves probably enter into the diet of a variety of birds and other animals.

	WEB	DESCRIPTION
House Spider *Theridion tepidariorum* Family Theridiidae	Web of loosely integrated threads apparently built with no established pattern. It is usually found under some shelter from rain — most commonly in a barn or house — often in comparatively dark upper angles of rooms, doorways, or window frames. Easiest to discover of all webs.	Female body ¼ inch long. Male body is more slender, to 1/6 inch long. Legs are nearly 3 times the length of the body. Highly variable in color pattern, but many have dark chestnut chevrons on both the top and underside of the abdomen. Appearance is generally dirty and dusty.
Golden-Silk Spider *Nephila clavipes* Family Araneidae	Inside a basic up to 4-foot square of heavy lines there may be secondary inner lines across corners. Inside this is a series of heavy, radial, non-sticky lines. In the center is a spiral of sticky lines with a hub, surrounded by a narrow spiral of sticky lines, then by a free circle, with bigger outside spiral.	Female to over 4/5 inch long. Back dark brown; abdomen olive with paired white and yellow spots and light line on the anterior end. Legs with conspicuous hairy tufts at 2 joints. Male about 1/3 length of female. Abdomen 2½ to 3 times as long as it is broad. Third pair of legs is shortest.
Arrow-Shaped Micrathena *Micrathena sagittata* Family Araneidae	Web to 1 foot or more across. Primary and secondary foundation lines support the many radii that extend to central circle, which is free of radii. Free hub may be conspicuous, and 2 or 3 may be controlled in width of the space by the spider's loosening or shortening the stabilimentum. The spiral is sticky.	Body of female to over 1/3 inch long; of male, to 1/5 inch. Female body obscurely arrow-shaped, with yellow, black, and red areas. Legs usually very little longer than the body. Male with narrow body, that is not arrow-shaped, with the abdomen slenderer than female's and widening slightly to the rear.
Cyclosa *Cyclosa conica* Family Araneidae	Normally a frame of heavy silk threads is strung vertically between two or more supports. Within this relatively rigid frame many radial threads are strung unusually close together, and in the center of this structure is strung a close spiral surrounded first by a free area, and then by a large, close spiral.	Female body is to 1/3 inch long and male body to 1/6 inch. There is a conspicuous tubercle on back of the abdomen, and eyes are on prominent tubercles. Size of tubercles varies greatly. Tubercles reduced in males, and most prominent in mature females. Color gray and white to black and white.
Zygiella *Zygiella montana* Family Araneidae	Web a modification of typical orb web, in which spiral is absent between two radii. Hub area is surrounded by narrow open area. From hub to the foundation lines a strong thread extends through area where spiral is missing. Here spider retreats to open-ended silken tube, and receives signals from prey.	Female to just over ¼ inch long; male to just under ¼ inch. Abdomen yellow to brown above with black-bordered conspicuous design. Forward part of back with narrow black margin around yellowish area. Usually elaborate design is visible on exposed upper surface of spider's body.
Marbled Spider *Araneus marmoreus* Family Araneidae	Web basically like that of *Zygiella*, but in place of a sector free of sticky spiral threads, it is continuous. Has a netted hub surrounded by narrow spiral area around which is narrow free area. Around this, in turn, is an extensive spiral and strong threads leading from the hub to spider's remote retreat.	Female to 3/5 inch long; male to 2/5 inch. Abdomen of female yellow with darker markings varying from brown to purple, with dark and light areas of about equal size. Cephalothorax, in front of abdomen, is yellow with darker lines along sides and in middle. Legs of both sexes rather stout and banded.
Long-Jawed Orb-Weaver *Tetragnatha elongata* Family Tetragnathidae	Web a relatively simple orb with few rays, no retreat, and no stabilizer. Hub is open, without radii, and occupied by spider. Surrounding hub is a narrow spiraled area, which is surrounded by a spiral-free area. This, in turn, is surrounded by a broad spiraled area that extends out to foundation lines.	Length of female, exclusive of jaws, to under 2/5 inch; male slightly smaller. Jaws of male more developed than those of female. Abdomens of some females, particularly in related species, may be swollen at forward section. Red-brown abdomen is silvery with various brown markings.
Bowl and Doily Spider *Frontinella pyramitela* Family Linyphiidae	Web a basic horizontal platform generously supported from a number of directions. Over this is a shallow, clearly defined bowl of silk supported above by threads leading irregularly to strong, main horizontal lines that extend to good supports. The maze of threads above bowl upsets prey as it flies past.	Female is 1/6 inch long—only minutely larger than the male. Carapace is an even brownish color. Abdomens marked in light and dark coarse pattern, conspicuous because of its bold design. But for the interesting web, the spider might remain inconspicuous.
Filmy Dome Spider *Linyphia marginata* Family Linyphiidae	Web so delicate that it may be passed up easily under most circumstances. It is best seen against a dark background. A platform consisting of a maze of threads has an inverted bowl or dome suspended over its center. Dome's lower opening may be five or more inches across. Dome is of porous net.	Female to 1/5 inch long and male to 1/6 inch long. Carapace is dark brown with a white border. Abdomen conspicuously egg-shaped with characteristic brown pattern against pale yellow background. Lateral stripes on abdomen are less conspicuous in the male than in the female.

ECOLOGY	RANGE	ECONOMY
Males court females, and are eaten if unwelcome. As many as 200 eggs laid in silken spheres hung in web 6-8 weeks after mating. Spiderlings hatch in one week and feed on each other through 5 molts, then leave cocoon to spend period on web of adult. Female may produce 9 cocoons in one season.	One mating may fertilize eggs for number of cocoons. Young may feed on scraps in adult's web after leaving cocoon. Web often placed in open over entrance to a dark area. Sometimes web is denser over one area, increasing protection for occupant. Ranges through United States.	Ability to adapt itself has made this species almost world-wide in its distribution. Animals are of no direct harm to man, and may destroy flies and mosquitoes. Also may provide food for wasps and birds. Webs used as adhesives by some birds in nest building.
Male lacks leg tufts. Male lives on the side of web opposite that occupied by female. Adult males do not build their own webs. Some species lay eggs in papery, hickory nut-sized cocoon firmly suspended in vegetation. Cannibalistic young hatch in mid-winter.	This species is found commonly in deep woods where there is little wind. Sticky spiral threads are yellow. Others are white. Sticky threads may pull radial threads out of line, and may be bounded by a number of non-sticky spiral threads that permit free movement of the builder.	Ranges from Florida west to California, with related species extending range. Parts of thread might be strong enough to be used in making cloth, but such use would be uneconomical. Radial lines are exceedingly strong, as are the bordering foundation lines. Webs may be repaired.
There is no free zone in the web area composed of the sticky spirals. Adult spider may hang in free area at the hub. There is no retreat zone such as is found in many webs. Stabilizing structure is relatively small. Little literature on reproduction in this species.	Species most frequently found in almost upright web suspended from stable vegetation in woods. *M. sagitatta* ranges through all states east of Oklahoma and Nebraska, with *M. gracilis* extending range to all states east of the Rockies. When in center of web, spider resembles horsefly.	Of no major economic importance and not so well known as it should be. Almost any amateur naturalist could, if opportunity presented itself, make some original observations and experimentations that would add to our scientific knowledge of this interesting species.
Two stabilizing structures extend across central area, permitting tightening and loosening of the web. Here spider may rest, as there is no retreat area on or off web. Spider itself closely resembles a piece of trash, and so is not easily noticed. Young hatch in egg sac.	Spider may shake the whole web, which possibly frightens away predaceous visitors. This is done while the spider hangs to the stabilimentum, which extends above and below the central hub. Range throughout the entire United States with the exception of Alaska and Hawaii.	Of no recognized possible economic importance, but must be admired for perfection of the orb webs. Perfection is partly due to protected area in which the spider lives, unexposed to strong wind and other violence. Web may be repaired successfully if it is damaged.
Center of orb is made of net itself instead of being a spiral. This center is surrounded first by a narrow and then by a broad spiraled area. A narrow wedge lacks the spiral, and the open space between two radii is halved by a strong signal thread that leads to the silken retreat on foundation line of web.	In a close relative, the eggs are enclosed in a series of small silken egg sacs that are then attached to a strong line that persists throughout winter and into spring. *Zygiella montana* ranges from North Carolina to and through New England west to the Rocky Mountains.	Of no great economic importance to man and his interests, but of major importance to those interested in variations in types of spider webs. Strong signal thread that runs through an empty sector in the spiral area to a remote but accessible area is of special interest to the student.
In closely related species, eggs are laid in strawberry-shaped, almost transparent, silken sacs either entirely away from the web or attached to some of the main threads. They do not appear to be strong enough to survive winter, and the plants on which they are placed may be easily killed during the winter.	Genus includes many species of great variety in size, pattern, and habit. Retreats are usually away from the orb web and connected to it by a strong signal cord or cords. This species nests in trees or shrubs in wooded areas and its range is most of United States.	Of no economic importance, but of interest to students of spider webs because here the retreat area is away from the major web. Limits of its foundation lines give animal independence from dangers of life on the web, at the same time allowing remote builder to control its web.
In males, jaws are longer than is the carapace (the part of back that lies in front of abdomen), and in females are almost as long. Males more slender than females. Silken egg sacs attached to twigs, and sparingly covered with beaded strings of greenish silk.	Webs are commonly found near water, and are frequently stretched over running water. Webs are sometimes stretched horizontally rather than vertically, as is common practice with most orb-weavers. Many species are known. This one ranges through continental United States.	Of no obvious economic importance, but does serve to eliminate some insects in a niche not commonly the responsibility of other spiders. When spider is extended in web it may resemble a bit of fallen twig, but it is alert in presence of potential meal.
Apparently relatively little is known about the life history of this often relatively common species. Females of closely related species have been taken with their egg sacs as early as April. Some individuals have been known to regrow limbs they have lost or injured.	This species is placed by some in the genus *Linyphia* by some entomologists. Its webs have been found in pine woods, in tall grasses, and in bushes, usually relatively close to the ground and well protected from weather. Ranges from New England to Florida, west to Arizona and South Dakota.	Little possibility that species has any great economic importance, but its involved and beautiful webs are of interest. In spite of their complicated structure, a bowl that has been destroyed may be completely rebuilt by the spider within a single day's time.
Spiders mature in early summer and the young may be found on their own diminutive webs by late summer. Adult lies under the dome awaiting arrival of an insect that falls on it after having been upset by threads strung above. Prey is quickly caught through holes in dome and drawn under for food.	Obviously such a flimsy nest is subject to injury by the elements and by animals, but the spiders are able to make quick repairs or, if necessary, to build a whole new construction. Common in woods, along paths, and close to streams throughout United States and in much of Europe.	Spider of no recognized economic importance to man, but the dome trap is unique and the reverse of the bowl trap made by the bowl and doily spider described earlier in this tabulation. This species is often seen on piles of rock, in underbrush, and near stone walls.

nature IN THE SCHOOL

In a little-known poem of the eighteenth century, "The Prophecy of Famine," by Charles Churchill, we read:

> "There webs were spread of more than common size,
> And half-starved spiders prey'd on half-starved flies."

We are all familiar with the courteous invitation a spider is supposed to have given to a fly; and in Pope's "Essay on Man" we find the spider used as an outstanding example of an animal's sensitivity to its environment.

> "The spider's touch, how exquisitely fine!
> Feels at each thread, and lives along the line."

On the more prosaic level of the classroom, it becomes obvious that the study of spiders and their webs is one that thrusts itself on many a schoolroom, and yet it is one that is usually neglected. The dust-covered, hanging threads of the spiders wave slowly over the heads of bored students who might, with the proper encouragement, make a study of these creatures. The life histories of such spiders was presented in an earlier insert.

Classes that wish to make collections of spider webs for study and reference may find the following suggestions helpful. If a web is sprayed with white shellac, somewhat as charcoal drawings are sprayed in art classes, the webs may become very sticky. If, while the web is in this condition, a black card is pushed broadside against the web, the shellac will leave a white outline on the black card. If this is covered with waxed paper, it can be filed, and become a part of a school collection.

The student should make a particular study of the web of some orb-weaver, and learn to name and identify its parts and their particular uses. He might also make a report of the ways in which spiders protect themselves, either by escaping from their webs or by effectively concealing themselves upon it. To what extent do they seem to rely upon camouflage for protection?

Some spiders among the orb-weavers make threads that men have made into silken cloth. The spiders are fastened into little holders, and the silk from a number of individuals is drawn out and spun into a thread, which in turn may be woven into cloth. The threads of some spiders have also been used as markers in surveying instruments. What other uses for spiders and their webs can you or your classmates think of?

Most spiders can be kept alive and comfortable in bottles, if water is supplied to them on damp blotting paper, cotton, or cloth. They may construct their webs in these bottles right before your eyes, and may repair them if they become damaged.

Dry-cleaning establishments can supply you with the component parts for excellent cages for observing spiders. Use two wire coat hangers. Fasten the hooks together with a piece of string so that the hangers are side-by-side. Twist one hanger so that its long bottom wire is at right angles to that of the second one. Tie these wires firmly at the place they intersect. Fasten a plastic bag over the hangers so that an opening of the bag is around the hooks, and tie it in place. The bag will hang downward, and the crossed hangers will keep it spread open. Fasten the lower end of the bag around the neck of a bottle with a rubber band and let it hang down. If a source of water is in the bottle, it may be reached by the spider; and if waste material collects in the bag, it should drop into the bottle. To feed the spider, fasten bottle containing flies or other insects to the bottom of the bag so that the insects may make their way upward into the bag where the spiders stay.

Locate a large orb-weaver web in a nearby woodland. Catch some fireflies. Toss a few into the web and see if the spiders attack them. Ascertain if the insects' light scares the spiders away, and if the fireflies seem to give more or less light when attacked by the spiders. Your observations may make it possible for you to locate orb-weaver webs even at night.

Notice how many of your spiders rest in their webs with their backs downward, and how many are able to run along the top on one or more threads. Can you find any that can run along the top of a single thread?

In an appropriate reference book, or in the twenty-second insert of this series, read about the activities of ballooning spiders. If possible, notice them when they are actively producing silk. The silk floats in the air until its upward pull is sufficient to carry the spider away. This method of travel is most effective when the air above the ground is rising, which occurs, for instance, when the air warms up on a summer's day.

It is instructive to see how these spiders perch on the top of some lawn plant, such as a dandelion. From atop such a perch, they point their abdomens into the air and expel a stream of silk that hardens instantly. A single ejection of silk may not be sufficient to send the spider off on a journey, but after a while the spider may be able to produce more silk, which, added to the first, may accomplish the desired result. In witnessing such a performance, the student will be able to estimate about how much silk can be produced by at least one of the creature's silk glands. The writer has seen the ballooning operation a number of times, at least once before the watchful eyes of a large class.

On a window sill, or even better on some old, weathered fence rail, find a few jumping spiders. These creatures leap into space in pursuit of their meals, letting out a silken line as they go. When they reach their prey they stop letting out line, crawl back up the line, and eat the quarry. Inside buildings, the line hangs from the ceiling, collects dust, and makes tidy housewives wonder how and why it got there. At first glance, it seems ridiculous that a spider should make a web that does not lead anywhere in particular! Notice how some jumping spiders have huge jaws, while others have jaws that seem more normal in size. The large-jawed spiders are males, and the jaws are used for holding the female—not for help in eating.

It is hoped that this article will foster interest in spiders, and perhaps send the student off on a spider hunt that will furnish both fun and learning. If you fall sick, are sent to jail, or are otherwise incapacitated, some kind of spider may come along to relieve the boredom! Seriously, these animals are always worth observing, and their study will prove both fascinating and profitable.

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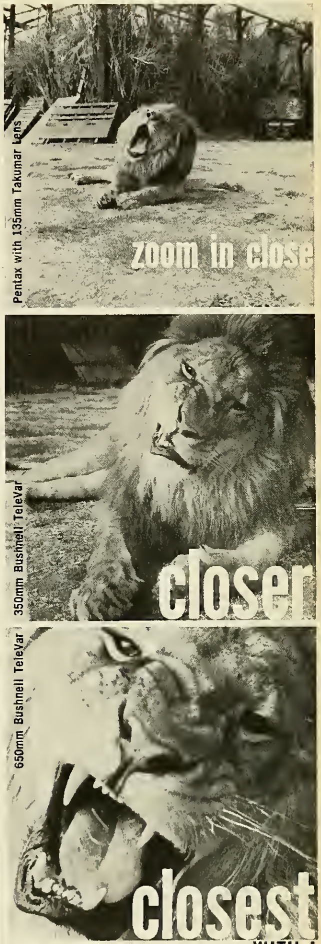

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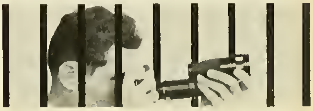
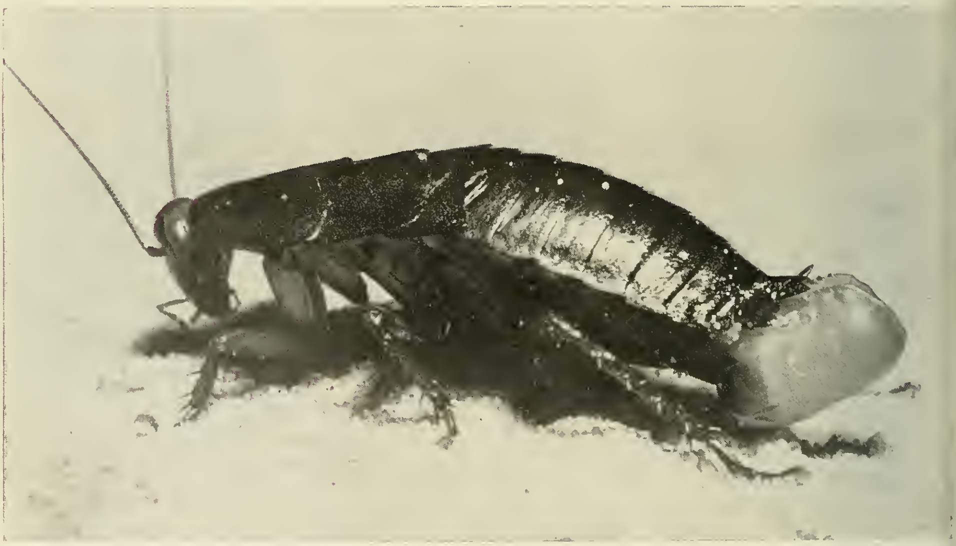


By F. A. McKittrick
T. Eisner
H. E. Evans

Mechanics of Species Survival

Roaches' hidden egg cases exemplify protective adaptation



Egg case, when it first emerges from female's body, is white and soft. In a few hours it becomes tan and hardened.

Digging stroke is made by head of the roach acting as a rake, *right*, with the mouthparts pressed down into sand.

One of the basic observable facts of nature that led Darwin to formulate his theory of natural selection was that the offspring of most species, in the early stages of their existence, greatly outnumber their parents. Despite this tendency to geometrical increase, Darwin noticed that the numbers of a given species actually stay rather constant. From this he correctly reasoned that, since more young are produced than actually survive, there must be competition for survival. This competition is usually referred to as the struggle for existence.

Prolific reproduction, then, is one basic requirement for the continued existence of most species. But just how prolific must a species be in order to survive? During its life span a codfish or a tapeworm, for instance, may produce eggs by the millions. Similarly, a solitary orchid flower may produce millions of seeds. But, clearly, a high reproductive rate is not the only key to survival, since many successful species—including man—have what is in fact a remarkably low rate of reproduction. Evidently the young of such species must be specially adapted to face and outlast the hazards of the struggle, or must somehow be protectively sheltered from them. Mechanisms for protecting offspring and increasing their chances of attaining maturity are commonplace evolutionary acquisitions

among both animals and plants. It is our purpose here to call attention to such mechanisms as they occur in a well-known, if poorly regarded, insect group—cockroaches.

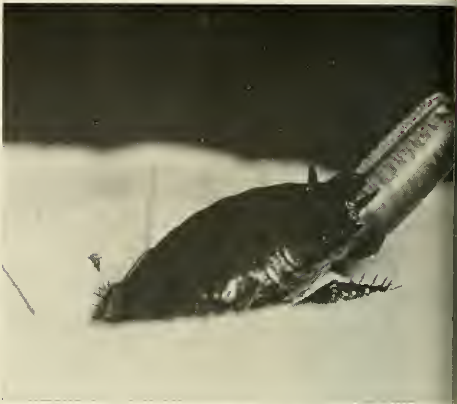
Remarkable as it may seem, the behavior of cockroaches has only recently come under careful study, despite the fact that for centuries many of their kind have been man's constant domestic companions, and that these sturdy insects have for years been chosen as subjects in his physiological laboratories. But cockroaches are active primarily at night: for this reason alone some of their most interesting habits have remained almost undetected.

SEVERAL years ago, one of us (Evans), while camped one spring night at Highlands Hammock State Park in the central part of Florida, noticed a group of cockroaches engaged in a most peculiar kind of activity. The species was *Eurycotis floridana* (Walker), a large reddish-brown roach, native and quite common to the area. All of the individuals were mature, gravid females, each having a fully formed egg case protruding in characteristic fashion from the rear of its abdomen. The roaches were on sandy terrain, and they were digging. As it turned out, each was preparing a small hole into which it then deposited the egg case, covering it with sand and finally smoothing over the surface so as to leave virtually no markings that might betray its activity.

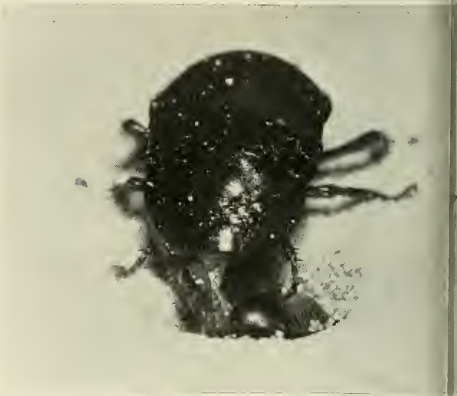
Eurycotis, we have found, does well in the laboratory. During its nocturnal egg-laying it is remarkably oblivious to outside disturbance. This has made it easy for us to study the animal's behavior at close range in all its fascinating detail. In the laboratory we keep the roaches on sand, in glass enclosures that prevent their escape and in which they can be watched and photographed with ease.

The first sign of the impending onset of egg-laying is the appearance of the egg case, which is slowly extruded from the genital chamber of the female. When it first emerges, the egg case is white and soft, but it gradually hardens over a period of several hours and becomes tanned to a dark brown. Egg cases are quite characteristic of roaches, but the number of eggs per case varies in different species. That of *Eurycotis* holds about twenty eggs, neatly arranged in two parallel rows within the packet.

With the completed egg case projecting from its rear, the roach now actively seeks out a place to begin digging. It ambles about at a leisurely pace, pauses occasionally to "inspect" the ground with its mouthparts, and then resumes wandering once more. Suddenly, it makes its first attempt to dig. The head is brought forward, is pressed into the sand, and is then pulled back abruptly in a rapid stroke that rakes a small heap of sand to the rear. This initial stroke may represent no more than one of the several false starts that the roach usually makes before settling on a definitive site. Once such a final location has been chosen—and we are still quite ignorant as to the specific environmental clues that the roach relies upon in making its choice—the digging proceeds without interruption, at the rate of a stroke every few seconds. Deeper and deeper the hole is carved, until eventually it reaches down about a



Funnel-shaped hole, dug to depth of about a centimeter, is the first step in egg-laying behavior of this cockroach.



Concealment of egg case is next step. Roach mouths an moistens it with saliva, then begins to cover it with sand

centimeter below the surface (see photos, *above*). In dr sand the entire procedure lasts about thirty minutes.

At this point the hole is more or less irregularly funnel shaped, and does not at all conform to the configuratio of the egg case. But the roach remedies this by shifting t a totally new kind of activity. It dribbles saliva onto th sand in the hole, and with the mouthparts picks up a fe grains at a time, removing them from one place and pressing them into another, until finally the hole is molde into a narrow, elongate trough, shaped quite precisely t hold the egg case. The molding of this trough is not rapid procedure: it may take the roach up to an hour t complete the job. It is interesting to note that the width o the head is about the same as the width of the egg case suggesting that the head itself might provide the gauge o which the roach relies while shaping the hole.

Now comes the main event—the laying of the egg case This act is simple—almost anticlimactic—and is completed within seconds. The roach lifts its head out of th

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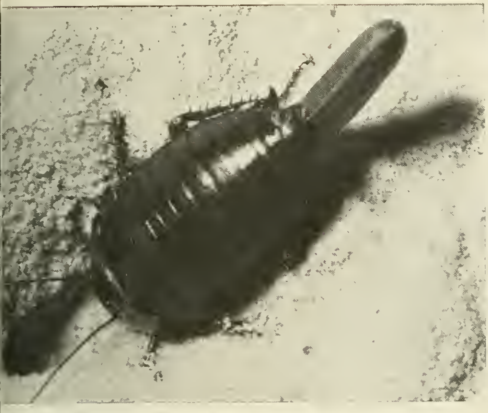
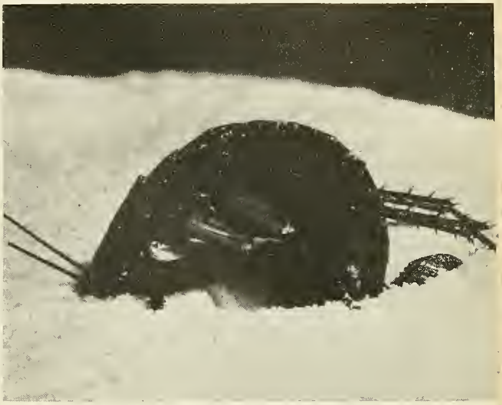
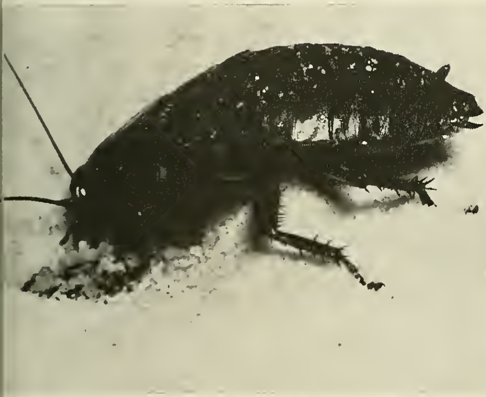


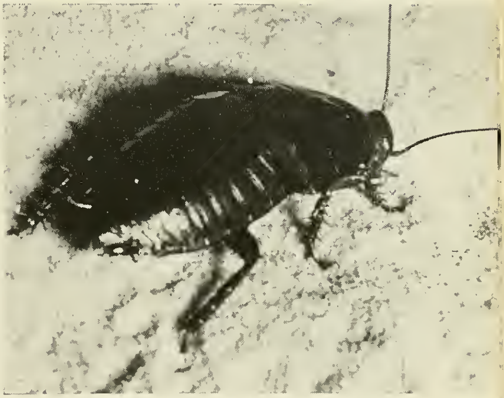
IT IS MOLDED with the mouthparts, using saliva-moistened ınd. Shape of the hole approximates that of the egg case.



ROACH STRADDLES PIT, arches its body upward, and slides case into hole by bending tip of abdomen forward and down.



GG CASE is now almost covered by sand, which roach picks p by mouthfuls from the pit edge and deposits on the case.



WHEN COMPLETELY COVERED, case is further concealed by a leveling and smoothing over of the entire excavated area.

ole and assumes a position directly above it, then arches s body upward and drags the rear of its abdomen, with ie egg case, forward into the hole. Once lowered into lace, the egg case is released from the genital armature. t this point, the positioning of the egg case usually still equires some adjustment. The roach turns round, grasps ne saw-toothed keel of the egg case with its mandibles, nd, by a process of pulling and tugging, maneuvers it that it fits perfectly within the trough.

THE egg case is now ready to be covered. Using its mouthparts, the roach picks up sand grains from the argins of the hole, thoroughly moistens them with saliva, nd then sticks them onto the egg case. The entire exposed urface of the egg case is roofed in this way with a dense, asted layer of sand, and completely disappears.

The final operation is a general smoothing over of the ntire region of activity. Again using its mouthparts, the oach simply picks up sand from one place and deposits it in another, eventually leveling out all major irregularities. It spends considerable time—often more than an hour—at this operation. The female's job is now completed, and she simply wanders off. Her major concern, for at least a brief period of time, will be the search for food. But within a few days—usually about eight—a new egg case will have matured in her body, and once more she will bury it and conceal it in the same elaborate way.

One of the remarkable things about this egg-laying behavior is its adaptability to different environments. When we collected *Eurycotis* in Florida, we noticed that one of the habitats in which it was most commonly found was dead, decaying logs. Within these logs, the roaches scurry about by the dozens, living in an internal labyrinth. We also found egg cases in these logs. But, instead of lying freely exposed within the passages, they were always hidden from view under small piles of shredded wood. We have since seen how *Eurycotis* lays its egg case in this type of habitat. It first carves a hole by chewing on the wood, using its powerful mandibles to tear away small pieces, one at a time. It then deposits the egg case in the carved-out depression and covers it with small wood shreds that are glued to the surface with saliva. Finally, the entire site is camouflaged with a loose cover of larger pieces of wood taken from the surroundings.

We must now ask ourselves about the function of this behavior. The first thing that comes to mind, obviously, is protection. But protection from what? Oddly, one of the main natural enemies may be *Eurycotis* itself. When we kept roaches in aluminum cages, we saw that many of their egg cases—which were now exposed conspicuously on the bottom of the cage—were eagerly devoured by the roaches, even when a surplus of other food was available to them. This kind of cannibalism could be almost completely prevented by transferring the roaches to sand or dead wood in which their egg cases could be buried. We say "almost completely," because even under these conditions, and especially when overcrowded, roaches at times chew away at each other's egg cases while these are protruding from the genital chamber.

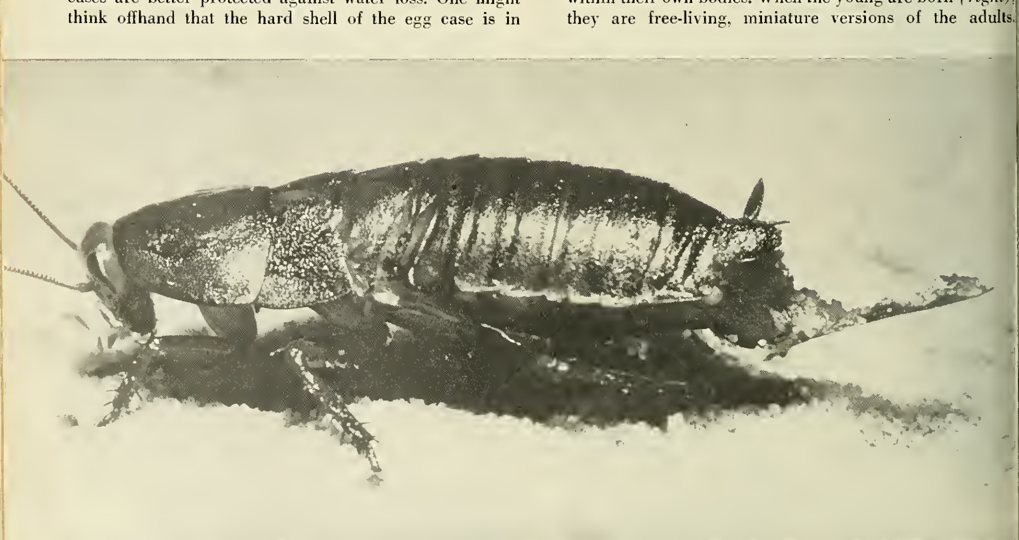
But roaches are not their own sole enemies. Ants, carabid beetles, and small rodents, to mention only a few, are each in their own ways potent menaces in the habitats frequented by *Eurycotis*. Burying the egg cases must help reduce the toll that would otherwise be taken by such predators. Then there are the egg parasites. Tiny wasps, for instance, lay their own eggs in roach egg cases, and the larvae undergo their entire development in them. It would be interesting to experiment with such wasps to determine if, when given a choice between exposed and concealed egg cases, the wasps are unable to locate the ones that have been buried.

Finally, there is the possibility that the buried egg cases are better protected against water loss. One might think offhand that the hard shell of the egg case is in itself an adequate shield against desiccation, but this i not so: the egg case that is exposed to the air loses wate quite rapidly at continuing low humidities.

After working with *Eurycotis*, it occurred to us that i might be worth while investigating some other species o roaches. We wanted to know, first of all, how widesprea this burying habit is and how it varies from one specie to another. One most interesting possibility was that b studying the egg-laying on a comparative basis—includin for study both generalized and more advanced species– one might be able to piece together the sequence of event that spelled the evolution of this behavior.

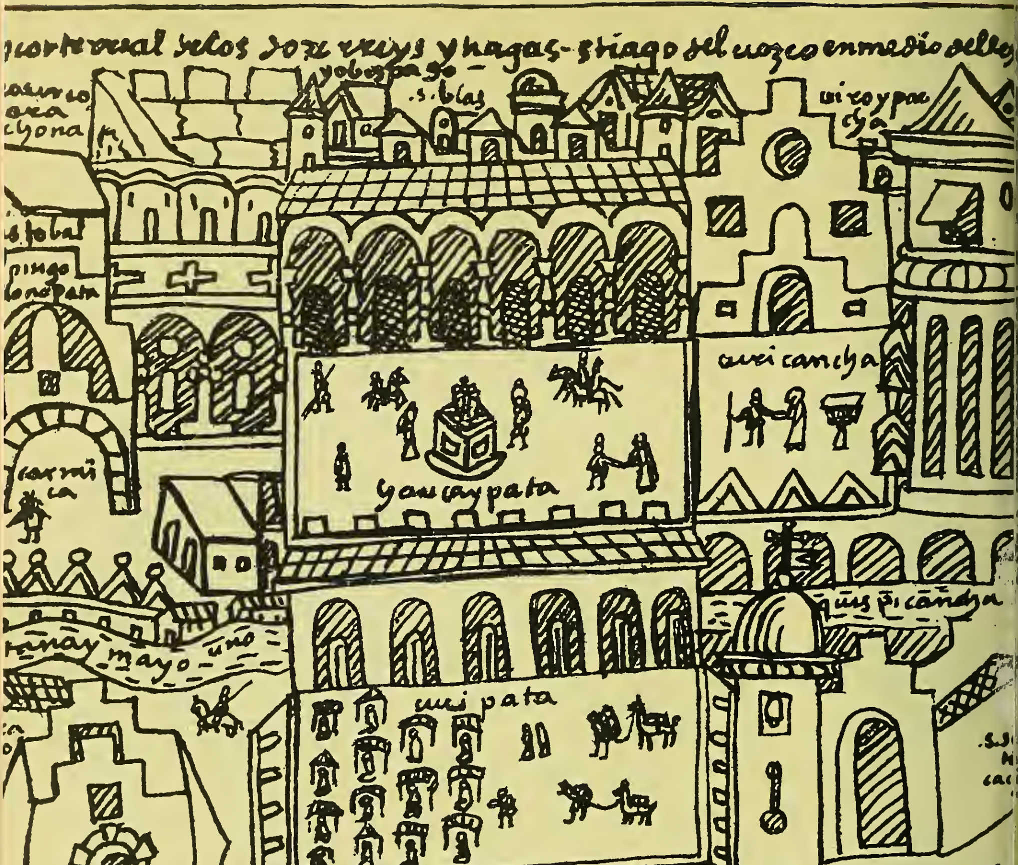
We have now worked on more than twenty specie from many areas of the world, including representatives of most known families. Our hopes are being realized Not only is the burying habit rather widespread, but it i also variable. Some of this variability is interesting i itself, even without going into the detailed evolutionar implications. For instance, some roaches dig with thei forelegs rather than with the head, others use both hea and forelegs. Some completely omit shaping the hole wit wet sand, and simply drop the egg case into the unmolde pit. One common native species, *Parcoblatta virginic* (Brunner), constructs an oblique tunnel instead of th usual open hole. Even the very act of laying is subject t variation. Some, like *Eurycotis*, lay the egg case fro above while straddling the hole; others turn round t lay, sliding the egg case into place by backing into the pit There are even a few species that simply drop their egg cases or glue them on an exposed surface, constructing n shelter whatever for their protection.

One should mention that there are some cockroache that never even lay their egg cases. As with the mammal among the vertebrates, they incubate the developing egg within their own bodies. When the young are born *(right)*, they are free-living, miniature versions of the adults.



Female roach, *above*, shows an extruded egg case that has been almost wholly eaten away by other colony members.

Reproduction patterns vary in roaches. Some do not lay egg cases but, like this *Diploptera*, bear living young, *right*


corte real delos doze reiys ynagas - stiago del cuzco enmedio delle
yobospago
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Part II

GVAMAN POMA DE AYALA

The post-Conquest chronicle of the Inca State's rise and fall

By JOHN V. MURRA

THE INCA STATE of highland South America had been spreading beyond the Cuzco area for less than a century by 1532. when the European invasion began. That e Incas' political and military feats were achieved so uickly seems incredible. From northernmost Ecuador to hile and Argentina. millions of people and dozens of thnic groups in mountain, tropic, and desert environments ad been defeated and incorporated into the Inca system etween 1438 and 1525.

Thus. Inca rule was alien and recent to most subject oples. But. as we have seen. this was not the first true te structure in the Andes. Guamán Poma de Ayala had gued indignantly against the notion spread by the Inca lite that they were the civilizers in the Andes and the rst to bring order out of barbarism. Although in his .200-page letter to the King of Spain Poma was eager to efend *all* Andean social systems against European libel nd destruction. he did not hesitate to distinguish the narowly Incaic from much earlier institutions and accomlishments. Such awareness is unusual in sources used for nca studies. and it makes Poma's work doubly valuable.

In the four-stage evolution of Andean culture and stateraft he presents in his *Nueva Corónica y Buen Gobierno.* 'oma had to face the fact that after "thousands of years" f benevolent rule by "legitimate dynasties." there came o power a man. Manco Capac. who "had no town or ountry. nor fields: no fortress. no caste. nor ancient kin . . . nd everything else they say and picture about the said ncas is a hoax." Poma deals only tangentially with the easons for the defeat of earlier rulers. They ended. Poma ays. and the reason for their downfall. he hints. lay in he personality of Manco's mother. Mama Huaco. She was 'a great idolator and witch who talked to the devils in ell . . . and with this she deceived the Indians of Cuzco . . and so she was obeyed and served and called queen. . . ."

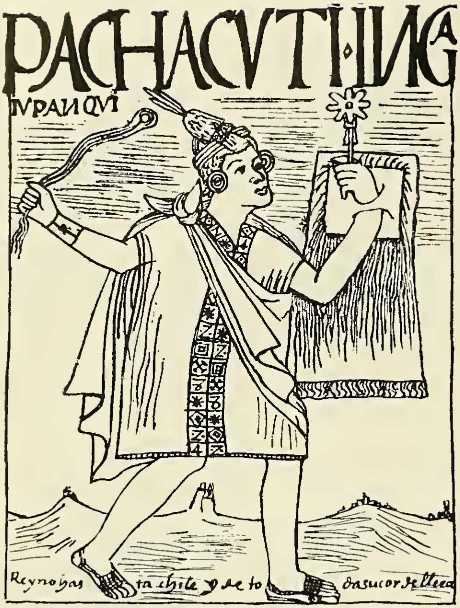
Poma's version of Inca state mythology is not very diferent from that recorded by other contemporary chronclers. Since there was no primogeniture, there were frequent civil wars and periods when several royal sons claimed to be king at the same time. Poma accepts a long count of the early kings and claims that the dynasty lasted some 1.600 years, although modern research indicates that even 300 years would probably be too long to allow for the consolidation of Inca rule in southern Peru, and its later expansion. But then. like most sixteenth-century Andeans, Poma was not very interested in exact dating.

Of all Inca history, the last century before 1532 was the most fascinating period. It was too recent to allow much manipulation by royal myth-makers: too many eyewitnesses of crucial events were still alive. Also. it was a period of rapid territorial expansion accompanied by many administrative, economic. and religious transformations. The personality that was associated most prominently with the expansion and internal reform was the ninth Inca King, Pachakuti, whose name means "cataclysm." Poma is not too reverent about his career: he explains the name by saying "there was much death in the time of this Inca and hunger and thirst and illness and God's punishment so that it did not rain for seven years and some say ten years and there were storms and the time was for weeping and burying the dead; and thus the said Inca was called Pachakuti. . . ."

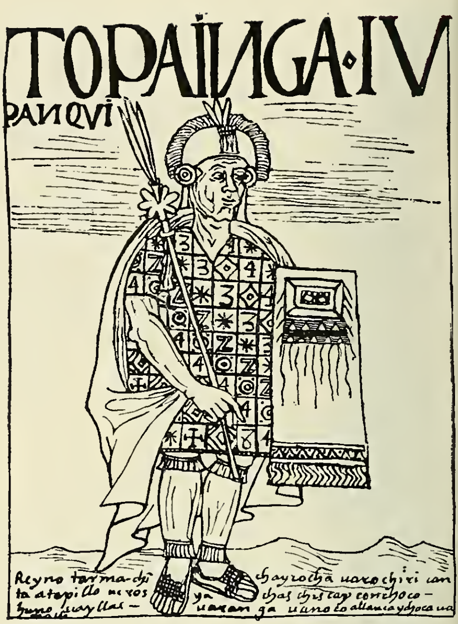
PACHAKUTI began to reign while his father. Viracocha was still alive. In fact. Viracocha had already selected another son. Urco, as his successor. However. when Cuzco was besieged by the neighboring Chanca. Pachakuti organized resistance, saved the city with alleged supernatural help, and eliminated his half-brother from the succession. Poma describes him "shooting at the enemy with his sling with a golden stone in it in his right hand and he defended himself with a shield on his left . . . he was a great eater and he drank a lot. a friend of wars and he was always victorious . . . he ruled all the way to Chile." He was the first Inca King to venture to the coastal oases, which produced much maize and cotton. Their inhabitants were relatively easy to defeat since their irrigation systems began in the highlands—he who controlled their sluice gates controlled them.

Pachakuti was apparently the first King to marry his own sister, Mama Anahuarque. Traditional explanations

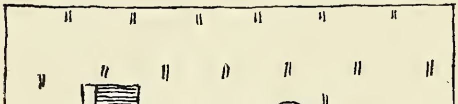
APITAL CITY OF CUZCO, the seat of Inca imperial authority n period prior to European invasion, is shown in sketch uthor included in his 1,200-page letter to King of Spain.


PACHACVTI·INGA
IVPANQVI
Reyno hasta chile y de to das u cordelleca

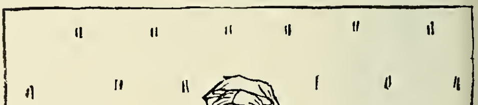
Pachakuti, the ninth Inca, is portrayed holding a sling and his shield. He was closely associated with expansion and internal reforms of Inca realm.


TOPAINGA·IV
PANQVI
Reyno tarma chi ta atapillo ne ros huno guayllas
ya uacan ga
chayrocha uarochiri con chas chiscay conchoco uano lo allancay dhoca ua

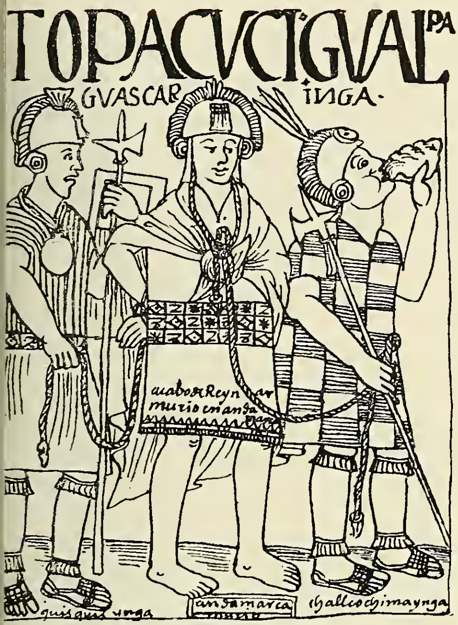
King Topa, Pachakuti's son, extended Inca sphere to north highlands and to the coast. He undertook administrative reforms that consolidated Inca rule.


Reyno hasta quichiua aymara

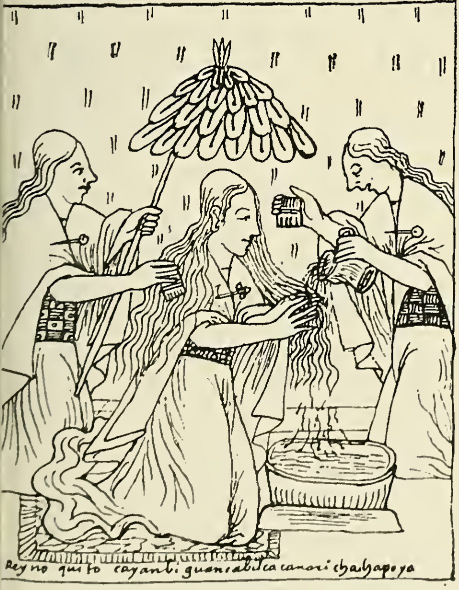
Chimbo Caua, the fifth Queen, is shown having a heart seizure. Poma states she had three attacks a day, during which "she shouted and pulled her hair."


Reyno condesuyo parina cocha lucana changa

Seventh Queen was described by author as "friend of raising little birds and monkeys. . . ." She also liked men, he says, "but the women not very much."



Last Inca, Huascar, is led to death by soldiers of Atahualpa, his brother. Their battle for throne facilitated the victory by the invading Europeans.


Reyno quito cayanbi guancabilca canari chachapoya

Topa's daughter, the eleventh Queen of the Incas, has her hair washed and combed by handmaidens. Poma says this Queen "liked to give many parties."

of royal incest at the Inca court refer to the majesty and high status of the king, which allegedly made any woman other than the king's sister inadequate as a potential queen. Recent research by Mrs. Maria R. de Diez-Canseco, a Peruvian historian, has suggested a new explanation: royal incest was an attempt to eliminate quarrels over succession by reducing the number of eligible princes.

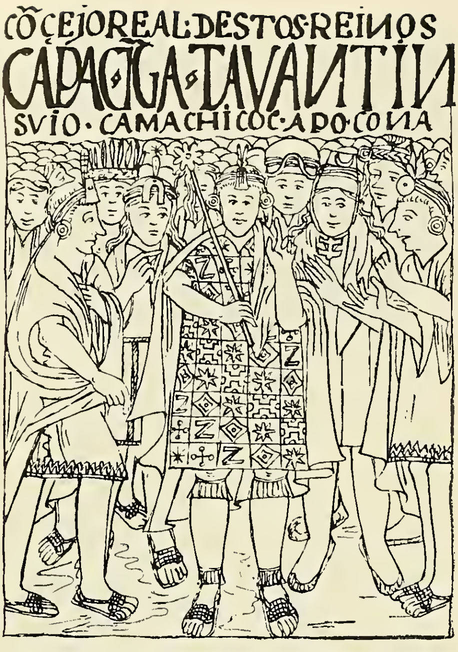
Another device to reduce succession squabbles was to associate one of the princes with the royal rule while his father was still alive. Pachakuti did not originate the custom, but because of the recency of his reign we have fuller data about his search for a worthy successor. The first heir he picked was Amaru Yupanqui, who took part in the Chilean campaigns. This nomination was withdrawn some years later, since Pachakuti thought the heir was not sufficiently "war-loving." The next one, Topa, who did much to extend the Inca realm, was a "greatest man of war." Poma lists many provinces Topa annexed, then claims "he died in Cuzco two hundred years old, he died of sheer old age, eating and sleeping, he never felt death."

According to Poma, it was Topa, not Pachakuti, who undertook the administrative reforms that consolidated Inca rule. It was Topa who "began to order that they build all the royal roads and bridges and he placed messengers and roadside way stations . . . and he ordered that all the districts be delimited and markers be placed on pastures and fields and hillsides and he built towns and he honored the lords and he ordered that the laws be obeyed and made new laws and he built up his own estate and that of his kin and warehouses, all with great order. . . ."

Topa's wife was Mama Ocllo, his sister, whom Poma describes as "very terrifying and beautiful . . . with a small face, gay at heart and calm, very jealous of her husband . . . They say her husband had 150 bastard sons."

Despite the several devices to insure peaceful succession, King Topa had to face the rebellion of one of his brothers, who had many followers among the royal lineages and the clergy of the Sun. In addition, the brother, while acting as a state official, "hid" some of the people he was supposed to enumerate in a census by not reporting them on the knot strings (quipu) of population. He apparently hoped to use them as the nucleus of an anti-Topa army. The plot was revealed and the rebels with all their lineage were killed. Then King Topa began to kill the villagers left out of the census. At that point, Mama Ocllo intervened and urged him to stop the killing. The Queen suggested that the survivors be used "in the service of the royal llamas, fields and shrines." Topa agreed, but insisted that these "rebels" should never again be counted in the census, and should devote full time to the king's estates. These retainers, known as *yanacona*, were a new, apparently unprecedented, group in Inca society. They were no longer peasants, who owed only a portion of their energy to the state but otherwise lived in traditional ways. Their removal from their homeland and their full-time duties to the king have led some scholars to classify them as slaves and to speculate that the Inca system was tending to become a slave society at the time of the European invasion, but this needs further study.

The next recorded King was a child when Topa died, and his official name indicates this: on becoming King he took the name of Huayna Capac, "Powerful Youth." He was the last Inca King to die an independent monarch,



State council of Tawantinsuyu, which means "realm of the four parts," actual name of Inca kingdom, is depicted as composed of royalty, with earplugs, and ethnic leaders.

before the European invasion began, but even in his time Francisco Pizarro's ships were prowling Ecuador's coast.

The fundamental changes occurring in the Inca social and economic system continued as it expanded. The kingdom grew so large that Huayna Capac began building a second capital, Tomebamba, in the northern territories he had conquered. This is the bland, official version, but there must be other reasons, too. For example, the inhabitants of the newly incorporated territory, the Cañari, were promoted to be personal bodyguards of the king, to the dismay of the royal kinfolk who had always had this privilege. The author hints of serious factional disputes between the royal lineages. Also, since each king had scores of sons, the royal lineages had grown very large and their pretentions and privileges created tension. All this erupted when Huayna Capac died: the usual succession squabble became a civil war coinciding with Pizarro's invasion.

At various places in his chronicle, Guamán Poma returns to this question: why was the Inca state so easily overthrown by a few hundred Europeans? This leads him to recount the war between the royal contenders, Huascar and Atahualpa. "So much dissension and fighting and this was the cause of death for so many lords and captains and poor Indians and the destruction of all the wealth . . . and while all this rioting went on the Spaniards dashed out of Castile to this kingdom and the Indians did not defend themselves like those of Chile. . . ." Some of his explanations for this lack of a defense are supernatural: when Huayna Capac's mummified body was brought to Cuzco "there was much weeping and crying . . . and what the devils told the new King as a message from his Inca ancestors was that men were due to come called Viracochas . . . And later the Christians arrived. . . ."

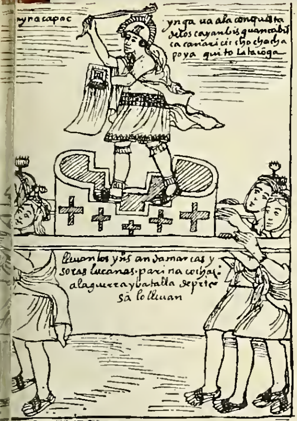
But elsewhere Poma emphasizes the unheard-of tactics of the invaders, their use of horses and armor: "all his people were scared, awed and each one began to run because they had never seen such a large animal and some men on top of them." Poma also observed that perhaps the character of Huayna Capac's heir, Huascar, had something to do with it: "from childhood on, the said Huascar was very proud and stingy and badly inclined. . . . He would have his captains killed and so they ran from him. He never wanted to be generous with his captains and soldiers. . . . He lost through pride his whole kingdom. . . ."

Faced with the need to organize a single state out of dozens of tribal units and confederacies, the Inca developed a double system of administration. The local gentry were left in office if they accepted Inca rule, while "federal" officials from Cuzco acted as inspectors, provincial governors, and policy-makers for the kingdom.

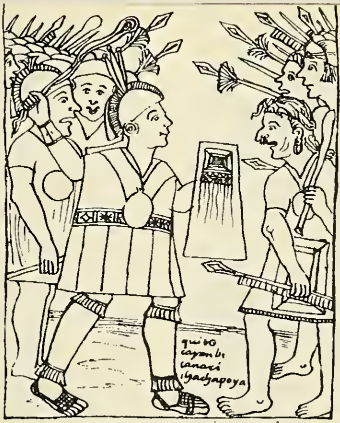
To leave local affairs in the hands of traditional ethnic leaders was a sound principle of colonial rule. The Inca used the method consistently: local shrines were left undisturbed, as were the gentry; local levies of people for the army or public works were sent where needed, led by their traditional authorities. In battle, they fought with their customary weapons. In Poma's pictures of war the ethnic groups are readily recognizable by their clothes, hair style, and armament. When King Huayna Capac went off to conquer the north, the job of carrying his fighting litter was entrusted to the Sora and Lucana, whose headdresses Poma draws differently from those of the Callahua, who carried the King's litter in peacetime.

Poma is an important source in our effort to determine which jobs in the bureaucracy were left to the local gentry and which were given to Inca descendants. Poma tells of a local official called the *suyuyoc*, in charge of *suyus* —tasks to be undertaken in turn by the various lineages and village groups in a valley (the word *suyu* also has other meanings). A *suyuyoc* "was to administer the community's [wealth] and that of the [local] gods, and of all kinds of fields, food and fruit, cloth and llamas, and mines as long as they belonged to the community, and of all the sacrifices. . . ." Such provincial administrators were sons of local leaders, but also "they must have ability and be diligent and fit for the job"—here, too, there was no automatic succession to the office. The young of the gentry were "given these jobs so they would learn their skills and how to keep accounts and to manage so they could succeed o the death of their fathers and would know what it was t govern the land." Such ethnic leaders can be distinguished readily from Inca officials in Poma's drawings, since the do not wear the distinctive, royal earplugs.

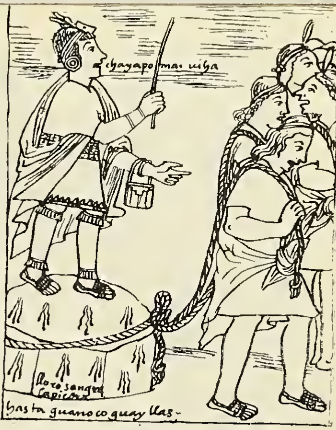
The contrast is most obvious in the drawing of the roya council that aided the king in governing the Inca state Since this body was abolished soon after the Europea invasion we know almost nothing of its composition o functions. Some sources give the impression that its mem bers had to be royal kin, but Poma's illustration contradict this: the three front figures are all royal princes with dis tended earlobes, but behind them is one of the author' relatives, with a horseshoe-shaped frontal ornament, an


yracapac
ynga ua ala conquista de los cayanbis guancabilca canari cicho chachapoya quito latacoga
lleuan los yngas andamarcas y soras lucanas. parinacochas. ala guerra y batalla de presa lo lleuan

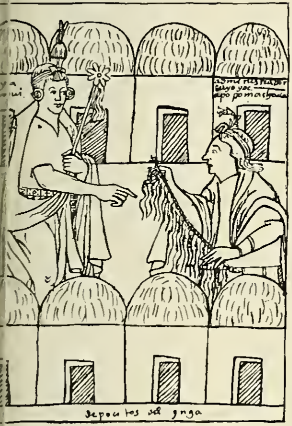
uayna Capac sets out to conquer e north, borne by Sora and Lucana.


quito
cayanbi
canari
chachapoya

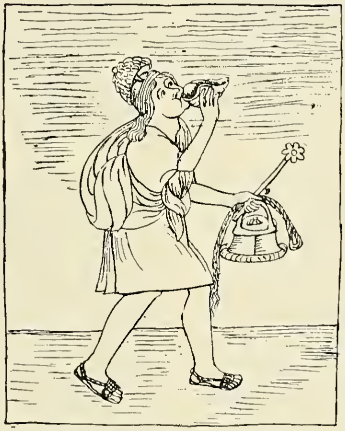
Inca army, with slings and shields, battles barefoot warriors of Ecuador.


chayapo ma uiha
lloro sangre
hasta guanoco guay llas-

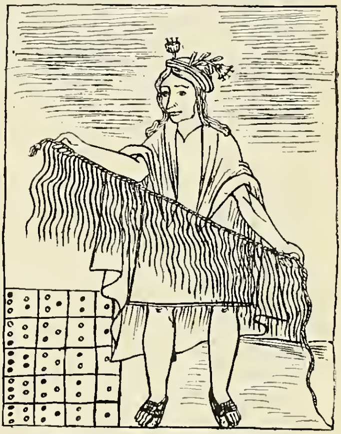
Prince Urco, son of Topa, had to move rock from Cuzco to Huanuco.


apo pomachaua
depositos del ynga

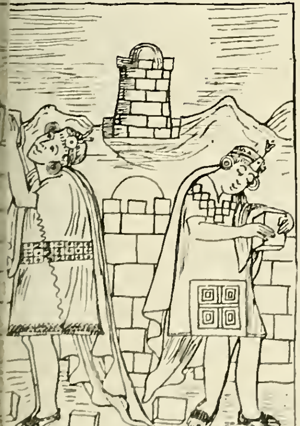
ing Topa checks state warehouse uipu shown by ancestor of Poma.



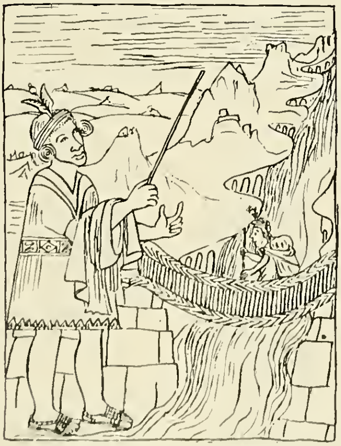
State messenger blows conch horn to warn next runner of his arrival.



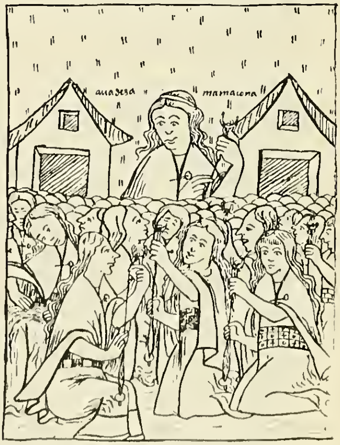
Treasurer, kin of author, holds a quipu. At left is version of abacus.



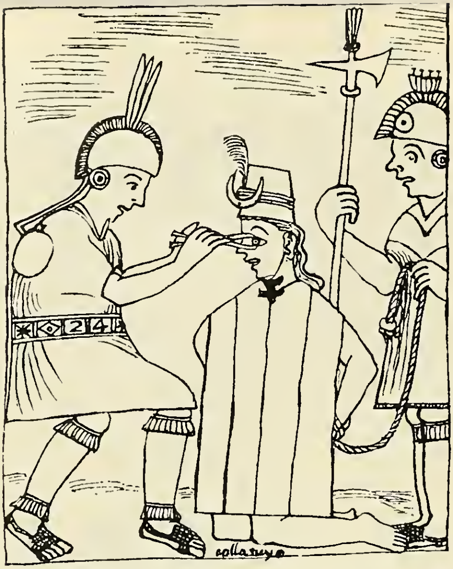
Boundary setters, officials of crown, erect landmarkers in Topa's reign.



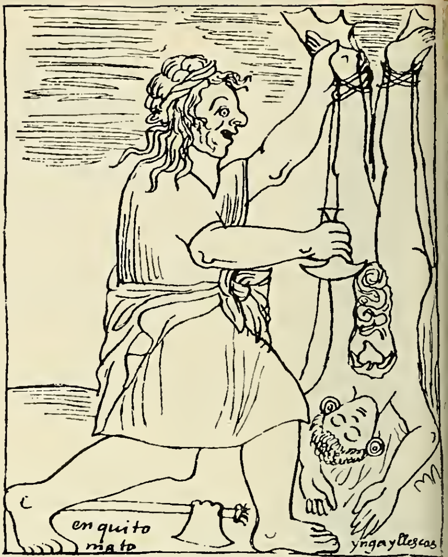
Inca official, from the Acos lineage, supervised bridges throughout land.


auadesa
mamacona

Selected maidens, the *aklya*, lived in seclusion; spun, wove for crown.



Captured rebel, a Colla tribesman of the southern Andes, is punished by Inca official, who removes eye with pincer.



Royal pretender is disemboweled by a captain during th European invasion. The victim's skin was made into a drum

behind him is the feather headdress of a man from the montaña forests of the Amazon. According to Poma, only four councilors were of royal descent; four more "were great lords from the north." Another four allegedly came from the south, and two each from east and west.

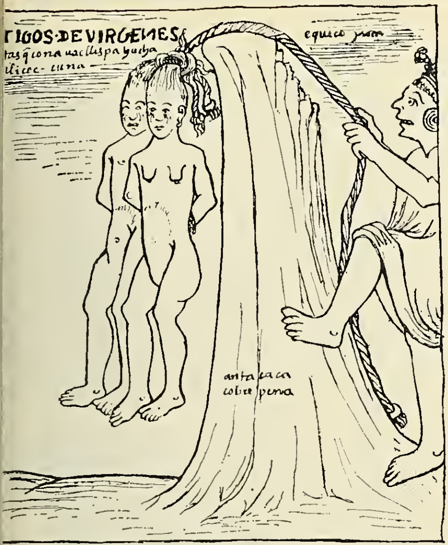
Today there is no way of checking Poma's information, which may well be erroneous in its details, since he wrote long after the council had ceased to function. Still, it is interesting to note how culturally authentic he is, even in his exaggerations: the members of the council are in multiples of four, favorite and magic number of the Incas. Even if the four regions were represented on the council by royal and not local administrators, the principle of such four-directional representation is probably reported accurately. Besides the four directions, the four royal princes also represented the fifth and sixth cardinal points in Andean thinking—up and down.

Below the royal council in Cuzco were a variety of officials responsible for the management and expansion of the kingdom. Most top generals were immediate relatives of the king. The opportunity of rising in the status system by military skill is suggested by other writers, but Poma was too wedded to the notion that hierarchical privileges were respected in the good old Inca days as opposed to their neglect by the Europeans. "They did not elect poor men . . . for leadership because royal highness and majesty cannot communicate with sons of peasants and if the lords were of low birth. the majesty of the Inca would be less valued." Elsewhere Poma is careful to indicate that no one was poor, but in discussing the state he is too eager to show his European reader the orderliness of Andean social structure and its respect for inherited rank to admit the evident opportunity for upward social mobility provided by the many wars the Inca waged.

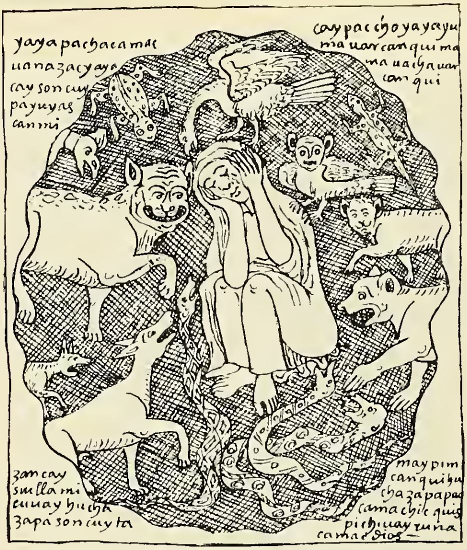
The major item of state revenue, which made possible the wars, the lavish court, and the administration, was the yield from state fields in various parts of the kingdom. These lands were worked by the local peasantry and produced revenues that were stored in state warehouses unti they were needed. Aside from labor on royal lands, th peasants "paid no tribute to the Inca or the queen, nor t the lords or any other person but they gave Indians o service and women in this kingdom. . . ." Peasant energy rather than products of the Indians' household economy thus formed the basis of the Inca state budget.

How the public domain was established—by alienatin peasant lands or by expanding terraced or irrigate areas—is not stressed in Poma's pages. He accepts th state's myth that given constant quarrels between variou ethnic groups over fields, pastures, and waters, the Inc had to intervene and delimit everybody's holdings to brin peace. Markers were set up, and an ideology was promu gated that lands left in the hands of the peasant communit were hence to be considered a benevolent grant from generous king. This contrasts with Poma's frequent exposure of Cuzco claims of benevolence in other areas.

Although the system of land tenure and personal services to the authorities was little more than an expansion c traditional Andean relationships to include the new powe of Cuzco, the Inca's state warehouses were a new elemer in the Andean landscape. They were much larger tha community storehouses, since they were meant to fee large armies and bureaucrats on tour with their retinue But they were also intended to supplement the ecologica production of a given region, which, in a country as broke up as the Andes, is frequently determined by what wi grow at a given altitude. "The Incas maintained war houses called *collca* in all provinces and those in th southern high mountains stored dried and frozen potatoe jerked llama meat and wool, while on the coast they we full of maize and sweet potatoes and chili peppers, cotto and coloring herbs and coca." The administrators an quipu-keepers of such warehouses were local men, ofte past the age for military or road-building service. Pon



EDUCER and willing *aklya* are hanged by their hair from liff, usual penalty for the transgression they committed.



Cave of beasts awaited suspects of treason and hideous crimes. If victim survived, he was deemed innocent, freed.

rew one, an ancestor of his, presenting the quipu "books" o a relative of the Inca come to check his accounting.

Poma was inordinately proud of the "order and civili-ation" of the Inca world as manifested in the census and he accounting it allowed. There were many kinds of cribes, "treasurers," and quipu-keepers. Some "put down verything that happened in each town . . . all accounts nd orderliness. These men had so much skill that through he knot-strings they knew so much that one would think was in script, with the strings they governed the whole ingdom." When necessary, the quipus could be carried to he provincial governor or even to Cuzco by the messenger ystem set up along the roads. A message-carrier would tart with the knot-string, "wearing a white feather on is head to shield him from the sun . . . and he carried shell trumpet to warn his partner farther on of his oming. . . . They were to take turns [carrying] and vere placed half a league apart so they could move fast. . . . They were sons of loyal chiefs and should not be lazy . . since they were not meant to stop, day or night, and hey ate from the warehouses of the Inca." Elsewhere 'oma suggests ". . . they were to have their lands in the ery places [where they served] and their llamas and verything they needed in the whole kingdom."

This may be an interesting hint to the changes the Inca ystem was undergoing: were the messengers becoming a ull-time occupational group? To be fed from state ware-ouses while on state duty was routine Andean practice. But to be granted land at the place of service implies eaving one's ethnic community and shifting away from raditional self-sufficiency and an ethnic definition of one's ondition. We do not know the answer to this question.

IT is quite probable that many of the so-called Inca roads, particularly on the coast, were actually pre-Incaic. But here is little doubt that much energy and thought was in-ested by Inca rulers in maintaining and expanding the oad system. "There were six royal roads in Inca times," says Poma, "which were administered by an Inca governor of the Anta lineage . . . they were measured and delimited and built, each eleven feet wide and on both sides stood stone markers and it went straight ahead . . . and on their sides they built way stations where one could rest and there were messengers and they were [well guarded] and the roads well paved and clean and with stones in the swamps . . . ." Across rivers stretched bridges of rope or sometimes balsa rafts, supervised by an Inca of the Acos lineage.

There is evidence that in the last decades before the European invasion various points of articulation within the Inca system of indirect rule were under considerable strain. While the kingdom was small it was easy to find royal relatives to staff the state council or the administrative corps; in time, the positions to be filled grew so numerous and the number of royal relatives compromised in dynastic disputes became so great, that a new source of reliable administrative personnel had to be found. Men from villages in the area around Cuzco, who were long familiar with Inca ways, were drafted for jobs, each village supplying officials for a particular function. Since the Inca system was a transitional one in which kinship was paramount as a way of creating loyalties, newly recruited officials were inducted or ritually adopted into the Inca kindred. Their ears were pierced and they were allowed to wear the earplugs symbolic of their new rank, even if the shapes and sizes of these plugs differed from the earplugs worn by royalty. "Inca does not always mean king," says Poma angrily, aware of the fictional nature of assimilated rank, "since Incas are lowborn too, potters and liars. . . ." Poma says some newly appointed inspectors "checked on many crimes and if they did not find them they carried stories and lies to the King [instead]. . . ."

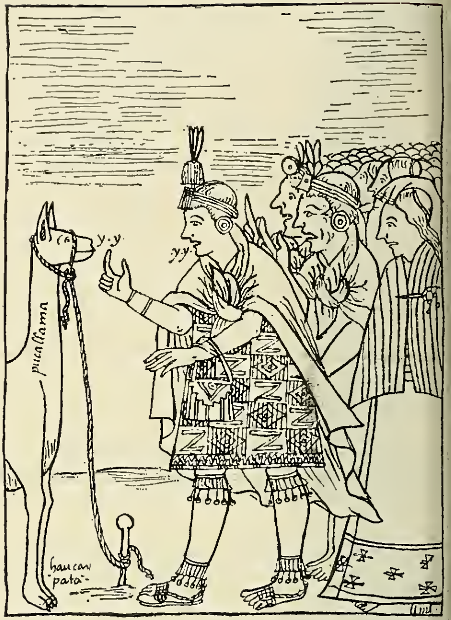
The shift from royal nepotism to administrative efficiency can be seen in the army, too. Top generals were royal relatives trained for the post from childhood, but peasants were the bulk of the fighting force. Each outfit served under its traditional leader, armed with traditional weapons. It is probable that King Huayna Capac had in mind a solution to such military problems when he established the Cañari as royal guards—since they were not of Cuzco ancestry and were but recently incorporated into the realm, Huayna Capac could hope to keep them out of the dynastic quarrels in which royal generals were prominent participants. By giving them land in the Cuzco area, he promoted them to high status and provided them with what in Inca terms was an independent income, yet kept them away from their traditional associations in southern Ecuador. Since the Cañari were full-time soldiers they could be used any time, unlike the peasant conscripts who tended to watch the agricultural calendar and to slip home if they felt their subsistence was threatened by their absence. Despite their high status, the Cañari guards were kept under tight control by the king. In some ways they were comparable to the *yana* servants of low status, discussed earlier: the Cañari, too, were a basically new group in Inca society. Removed from their homeland, Ecuador, they were made state retainers. Poma had little use for them: "they were rebels, thieves and liars."

A final glance at emergent groups in Inca society focuses on the *aklya*, weaving girls who were kept in "nunneries" according to the Europeans. Like the *yana* and Cañari, the *aklya* were plucked from their ethnic, peasant background, and assigned to professional specialization for the benefit of the state. Also, they were forbidden to marry. While agricultural and military retainers are frequently found throughout the world, the idea of a full-time, female corps of state weavers is peculiarly Andean.

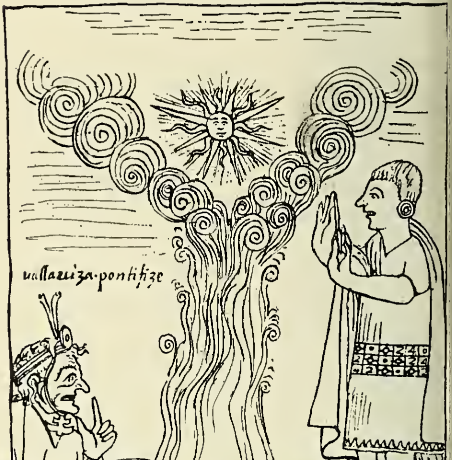
Textiles in the Andes have long been admired for their excellence. We know that for thousands of years before the Incas, garments were a favorite offering to the gods, an important indicator of social status, and the preferred gift between individuals. This made clothing a convenient token in the Incas' manipulation of people, and in time clothes became one of the main rewards for those serving the state. Soldiers and generals, carriers of the state's provisions, and pilgrims to the Sun's shrines expected and felt well rewarded with garments presented to them from the king's warehouses. Such institutionalized generosity could be displayed only because throughout the kingdom millions of women were weaving annually to replenish the textile stockpile of the Inca state. At some point in Inca history widespread but part-time devotion to weaving was no longer adequate: the full-time *aklya* were established and their removal from their families was justified as a "selection" for higher, religiously flavored duties.

Poma's data on the *aklya* are the most detailed available to us. He claims there were twelve categories or stages: "six kinds of virgins of the idols and six other kinds of ordinary virgins." They differed in status, age, and degree of availability to the attentions of the kings and their captains. As did the European observers, Poma stresses the nunlike qualities of these women. He devotes a full page to the punishment of those who seduced an *aklya:* for example, hanging of both parties by the hair from a cliff, "where they suffer until they die," if both had agreed to the transgression. Even if the *aklya* were unwillingly seduced or forced, she "received fifty lashes with a rope with a stone at its end, and she ended up half-dead. . . ."

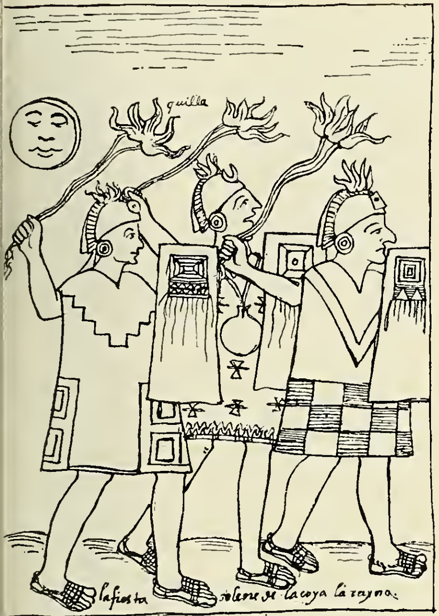
Still, if one checks Poma's description of the several



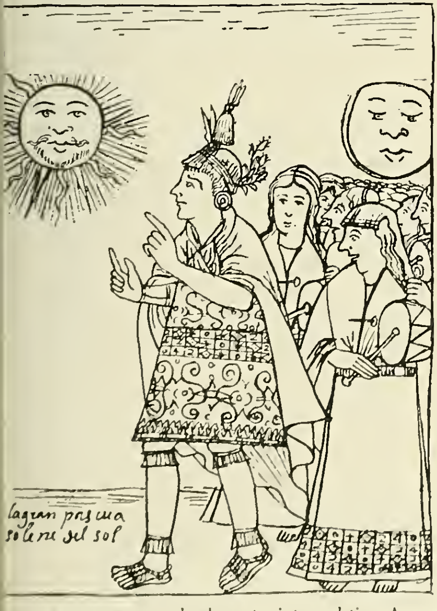
Religious ceremony of members of royal families, which was called *waricza arawi,* entailed singing to sacred llama



Burnt sacrifice is made by an Inca, right, and a pries from the southern Andes. This sacrifice occurred in July


quilla
lafiesta solene de la coya la rayna.

STIVAL OF MOON, celebrated in Cuzco at autumn equinox, as marked by armed men whose slings drove out illnesses.



AJOR SUN FESTIVAL took place at winter solstice. Among crifices, Poma says, was the burial of 500 living children.

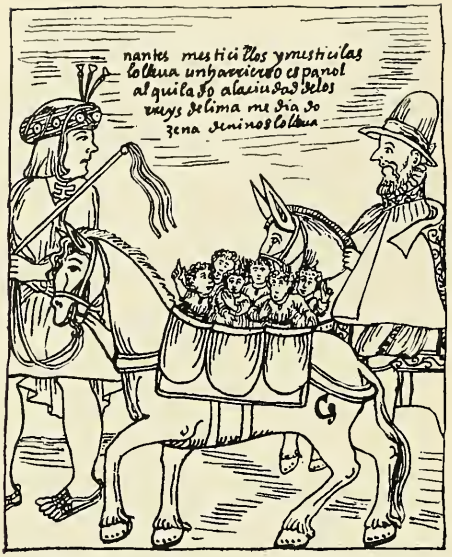
kinds of young women lost to the community, the nunlike analogy recedes: "virgins of secondary shrines and idols, called *sumac acllap catiquin* ('those who follow the beautiful chosen ones') thirty-five years old, these spun and wove the clothes of the shrines. . . ." He also lists "another house of tiny virgins, called *uinachicoc aclla* ('chosen to make them grow') who entered at the age of four to learn to work, weave, spin . . . and they stayed in this house until they were ten, learning a woman's job. . . ." Others were "*acllas* of the Inca himself, some of them were virgins, some corrupted and concubines of the Inca. . . ."

The cruel penalties exacted from molesters of the *aklya* are matched in Inca law by the punishments that were meted out to other criminals. There were few fines or jails in the Andes. The Inca state, like the peasant community before it, preferred to administer corporal punishment, to which the state added the penalty of wiping out a culprit's entire lineage in cases of "treason" or rebellion.

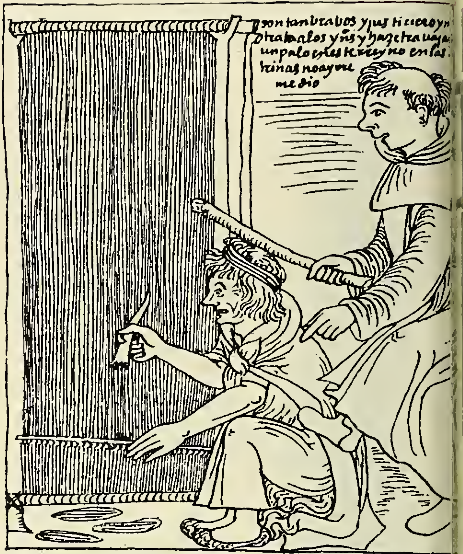
The most widely publicized state sanctions affected the pretenders defeated in battles of royal succession. "They had drums made of lords who had been rebels and traitors," reports Poma, "drums made of their whole body dressed in the clothes of their rank. they called these drums *runa tinya,* human drums . . . and they used the dead man's hand to slap the drum's belly." This also happened during the European invasion when a captain, "son of an ordinary peasant Indian," took advantage of the chaos in the country to kill and make a drum of one of the royal pretenders, a youth of twenty. But the murderer was killed in turn by the Indians "because he had done much other harm . . . and thus ended the life of the poor captain," says Poma, abandoning his hierarchical stance to reveal a sympathy with local men who could act on their anti-Inca feelings.

ONE form of state punishment deserves particular attention. According to Poma, a person accused of especially heinous crimes was taken to "a cave below ground, very dark where they raise poisonous snakes, pumas and jaguars, bears, foxes, dogs and mountain cats, vultures and owls, frogs and lizards. They had very many of these animals to punish the rogues and delinquents . . . whom they placed so they would be eaten alive. And some were not eaten by a miracle of god and they locked him up for two days . . . and if he escaped from these animals, the Inca ordered that he be taken out and freed without blemish and forgave him and returned him to his honors. . . ." Such ordeal caves existed only in cities: "First, because only large cities require them and second, because the majesty of the Inca was the highest justice and third, with this fear, the country did not dare rise . . . they said nothing."

The Inca state and the royal dynasty were also extremely active in religious matters. While local Andean shrines and cults were allowed to continue. the state church demanded much of the peasantry, for church revenues, like those of the state. consisted of peasant energy—in this case expended on church estates, which were separate from those of the state. King Pachakuti, the great transformer of the Andean social order, thought that religion could also play a unifying role in a kingdom that was characterized by extreme cultural and religious diversity. He made a deliberate effort to creat a state cult of a Supreme Being, who was also the Creator, known to the Inca as Teczi Wiraqocha. The cult was meant to supersede the earlier, local Sun worship Guamán Poma is one of the few sources to reproduce a


nantes mesticillos ymesticilas
lolkua unharriero español
alquilado alaciudad delos
reys delima me dia do
zena deninos lolkua

Jammed in saddlebags, babies allegedly sired by priests are taken to Lima. Poma abhorred invaders' miscegenation.


son tan bravos y jus ticieroyn
otratanalos y ñs y haze trauaja
un palo coles tiene y no en las
hinas no ay que
me dio

Martin de Murua, European chronicler-priest whom Po
detested, is represented compelling an old woman to wea

prayer to this new deity: "Oh, fundamental Wiraqocha, nearby Wiraqocha, wherever you are in the sky or in the world or at the end of the world, listen to me Creator of the world and of man, wherever you are, listen to me."

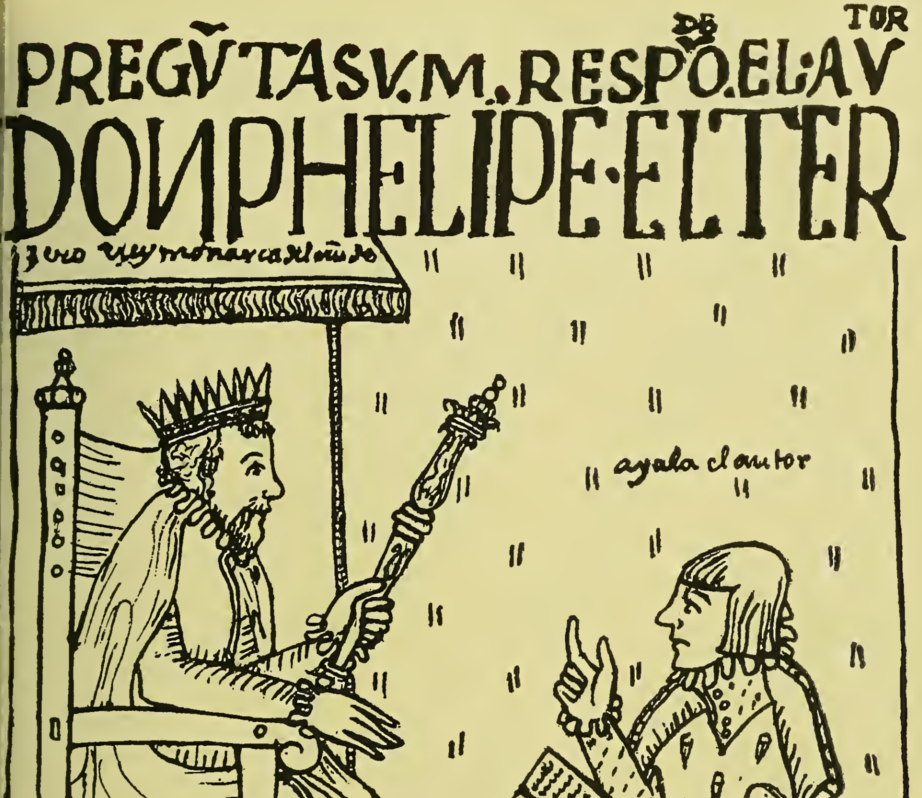
Most of Poma's discussion of religion, however, is phrased in terms of the Cuzco ceremonial calendar, which in time became the state cycle of ceremonies and festivals. Thus, the Sun feast took place at the winter solstice, "when they made great sacrifices to the Sun, much gold and silver and pottery and they bury five hundred innocent children . . . alive and upright with their silver and golden vessels and much powdered sea shells and llamas and after the sacrifice they had a great party, they ate and drank at the Sun's expense and they danced in the public plaza." Poma contrasts this holiday with that of the Moon, which was celebrated at the autumn equinox: "of all the planets and stars, the Moon is queen, and wife of the Sun and thus it was the feast of the Moon; women divert themselves most during this month . . . and they treat the men and during this month also the Incas ordered that illness be driven from the towns . . . the men armed as if going to war, discharge their slings, saying in a loud voice: 'Out, illness and epidemic, leave the people and this town, leave us.' "

The bulk of the material quoted and discussed in this article comes from the first third of Poma's letter to the King. At the conclusion of this section, Guamán Poma turns to the world he lived in, colonial Peru eighty years after the European invasion. Here, his text oscillates between an anguished recital of cruelties, abuses, and horrors committed by the invaders and a methodical, if repetiti
attempt to devise a "good government" from fragments
Inca organization still familiar to Andean Indians in 161

Looking to the past, he addressed the European reade
"Look here, Christian, see all the order, good and ba
Now, Christian reader, I have divided it into two par
the bad set aside to be punished, with the good to ser
God and His Majesty. Look here, Christian reader . .
did not find the Indians to be so greedy of gold and silv
nor did I find an Indian to owe a hundred pesos, nor lia
gamblers or idlers or whores, nor do they take thir
from each other. . . . Do not be afraid Christian read
of the idolatry and ancient fights, the Indians were in err
as heathen, they missed the true path, just [as] the Spa
ards once had idols . . . and the Indians as barbarians a
gentiles wept over their broken idols at the time of t
invasion. . . . It is you who have it all, disobedient to yo
father and mother and to the prelates and king and if y
deny God, you deny him firmly. All this is yours, and y
teach it all to the poor Indians . . . it seems to me, Christi
that all of you are damned to hell."

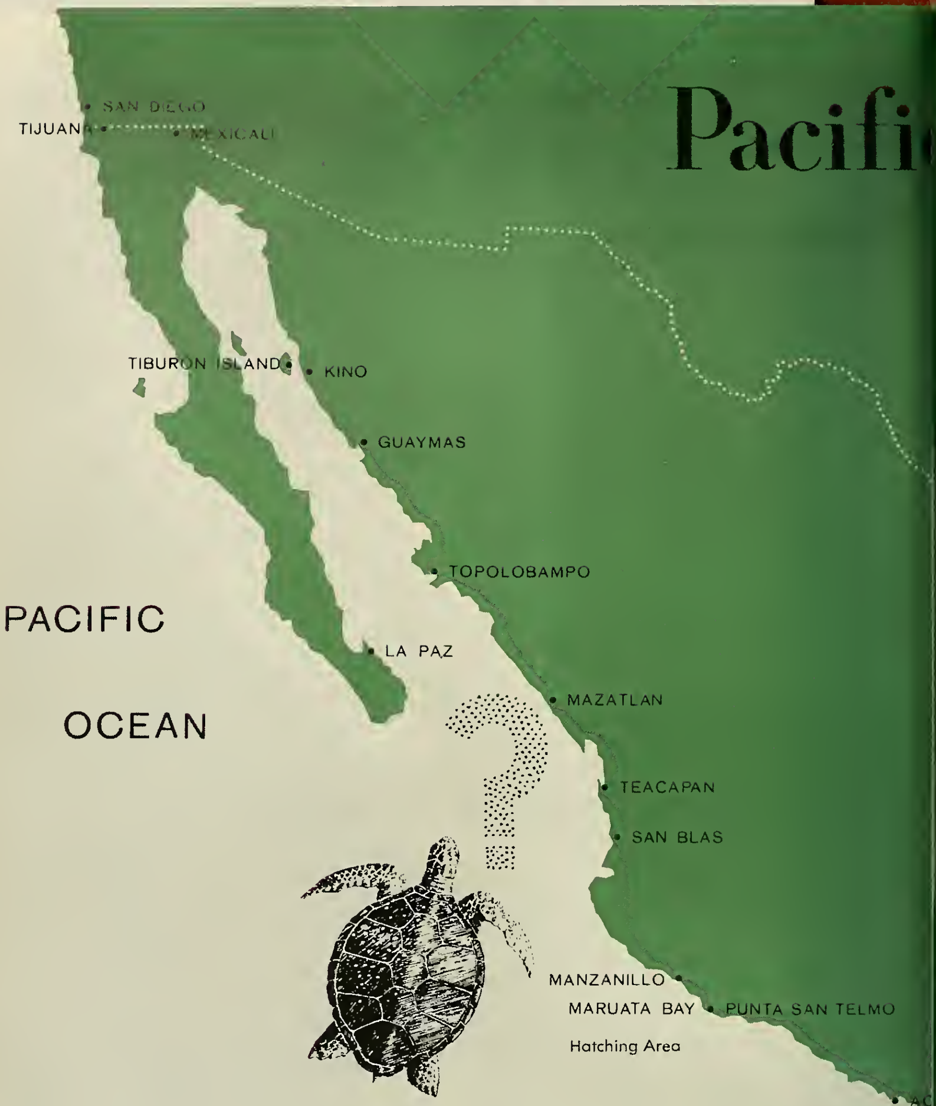
After 809 more pages of angry protest, Guamán Po
finished his book. He hoped the King would see
that he would read the many pages of royal questions Po
had anticipated in his fantasies, and that he would consi
Poma's answers on how to govern Peru. "I crave the e
and souls of the Christians of the world," Poma says. "Lo
here, Christians of the world, some will weep [on readi
the book], some will laugh, others will damn it. Some w
entrust me to God, others will come apart from sheer ang
but some will want to hold this book and chronicle in th
hands to restrain their soul and conscience and hearts. .

Dr. Murra, formerly of Vassar College, is now Visiting Professor of Anthropology, Yale University. He concludes here his discussion of Poma's presentation of Andean life.


PREGṼTAS V.M. RESPÕ. DE EL AVTOR
DON PHELIPE EL TER
zero rrey monarca del mundo
ayala el autor

thor's dream of presenting chronicle to Philip III, ng of Spain, was never realized. But the Andean Indian did meet the King in fantasy, in this drawing of himself kneeling before the ruler of the oppressors of his people.

Pacifi


SAN DIEGO
TIJUANA
MEXICALI
TIBURON ISLAND
KINO
GUAYMAS
TOPOLOBAMPO
PACIFIC
OCEAN
LA PAZ
MAZATLAN
TEACAPAN
SAN BLAS
MANZANILLO
MARUATA BAY
PUNTA SAN TELMO
Hatching Area
AC

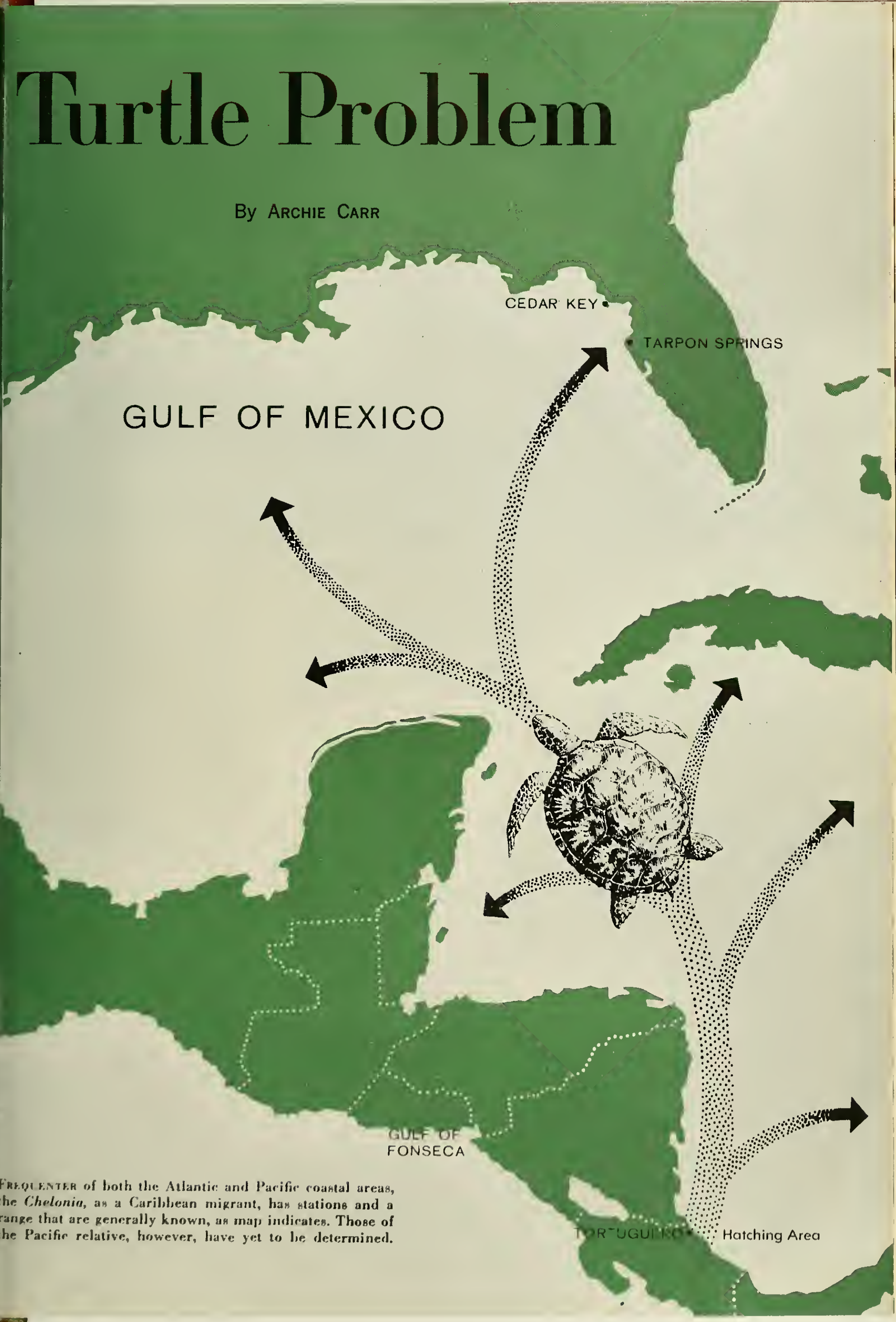
Mexico's coast yields information on a matter of melanis

When I was gathering information for my *Handbook of Turtles* ten years ago, I was struck by how little was known of the sea turtle fauna of the Pacific coast of the Americas. During the decade since that time a good deal has been learned about sea turtles in some areas, but the eastern Pacific has remained neglected territory. Even in Mexico, despite the seasonal immigration of zoologists from the United States, recorded observations are so scant and so rarely supported by good identifications, and specimens in museums are so few, that it has not been possible to tell which kinds of turtles nest on the coast, or even which kinds turn up as strays.

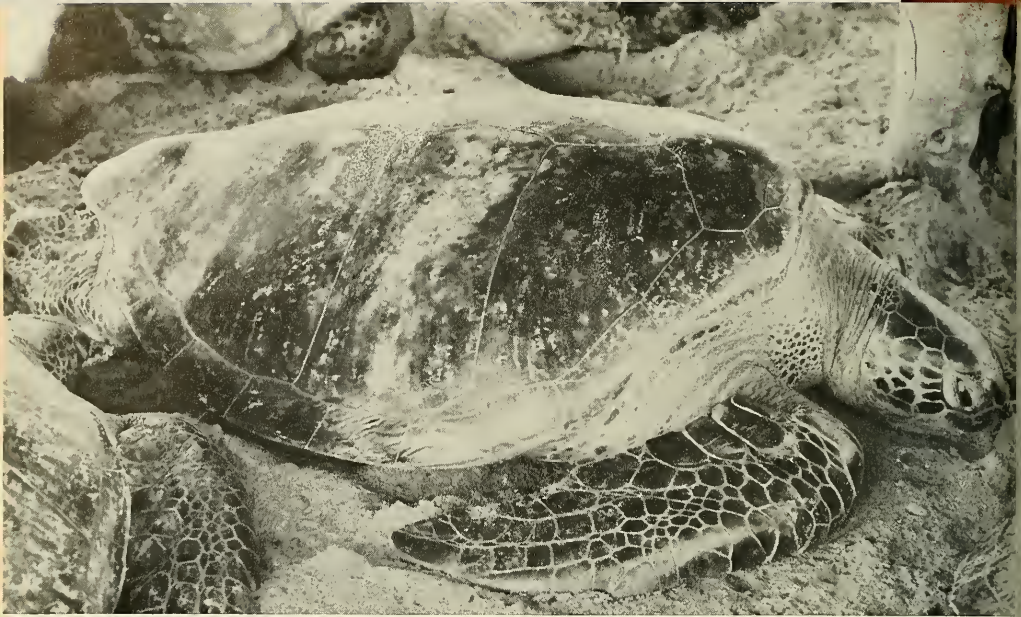
During the summer of 1960 I began to feel so uneasy about this that I set out to see what these neglected tu
were like. During August and Sep
ber I took the hot road south
through Sonora and Sinaloa an
down into Nayarit, the states of
ico that make up the eastern sho
the Gulf of California. I turned
ward whenever the way looked p
ising, and managed to reach the
at the following places: Puerto

Turtle Problem

By Archie Carr


CEDAR KEY
TARPON SPRINGS
GULF OF MEXICO
GULF OF FONSECA
TORTUGUERO
Hatching Area

Frequenter of both the Atlantic and Pacific coastal areas, the *Chelonia*, as a Caribbean migrant, has stations and a range that are generally known, as map indicates. Those of the Pacific relative, however, have yet to be determined.



"**Black**" **turtle**, the *Chelonia* of the eastern Pacific, was photographed by the author at Kino Bay along Gulf of California. Note distinguishing melanism of this immatu female—the dark coloration of head, flippers, and she

Kino Nuevo and the shores of Kino Bay, Guaymas and adjacent beaches, in the State of Sonora; Topolobampo and the shores of Ohura Bay, Mazatlán, Sábalo, Los Serritos, Teacapán, and Tamboritos, in the State of Sinaloa; San Blas, and Matanchén, in the State of Nayarit. Although there is still a lot to be learned about West Coast turtles, at least I can speak of this fauna with more confidence, and a start has been made in tracing the travels of the local race of *Chelonia*—a handsome color phase called locally by Spanish names that all mean "black" turtle.

During previous short trips to the Mexican Pacific coast, the loose terminology the fishermen used had hindered my questioning the residents about sea turtles. *Caguama*, for instance, is evidently an old Carib name for the loggerhead—a term that in pre-Columbian times spread to the Pacific coast. In southern Mexico and Central America the word is now in general use for the ridley (*Lepidochelys*). North of Acapulco, however, it means simply "sea turtle." Thus, to ask if the *caguama* occurs in a given place is likely to produce little information on the kinds of turtles that actually live there. Having recognized this before my 1960 trip, I began asking fishermen to describe more precisely the kind of *caguama* they knew, and was able to work out this list of equivalent names:

- *carey*, the rarely observed hawksbill (*Eretmochelys*);
- *galápago*, the leatherback, known as a straggler (*Dermochelys*);
- *mestiza*, exceptionally light-colored examples of the ridley (*Lepidochelys*) or of the "black" turtle (*Chelonia*), possibly also the loggerhead (*Caretta*), if it occurs in the region;
- *golfina* (or in places where it alone occurs, simply *caguama*), the ridley (*Lepidochelys*);
- *caguama prieta* or *tortuga negra*, the "black"—elsewhere, green—turtle (*Chelonia*).

In making this survey, I resorted to all possible means of collecting information. Besides systematically questioning local fishermen and turtle and egg hunters, I walked beaches, searched dumps for turtle shells and bones, visited markets, crawls, and docks where turtles were landed, and cruised 300 miles in offshore waters.

In the 650 miles from Kino to San Blas, including much of the eastern shore of the Gulf of California and the coast south of the mouth of the Gulf, only two kinds of sea turtles, *Lepidochelys* and *Chelonia*, seem to occur regularly. Of the live turtles I saw, and of the shells, bones, nests, trac and carcasses found in markets total of about 280 animals—all b one were either *Lepidochelys* or *Ch* *onia*. The exception was a half-grow dead hawksbill that I found on t beach at Kino, two miles north of t village. Nowhere along the coast di see the leatherback, although the pe ple were acquainted with it as a stra gler and at several places referr vaguely to distant leatherback nesti grounds. Although only the one de hawksbill was seen, it was alleg nearly everywhere that hawksbi came ashore to nest once in a while. was also said they arrived in fe numbers than did ridleys, and favor either the same places as the ridley "rockier places"—which presuma meant sections of beach bounded rocky promontories. I had previou heard this same report at several calities along the Central Americ coast, particularly in the Gulf of F seca in Honduras and El Salvador, I have not been able to corroborate.

The one sea turtle of which no si was found, either directly or throu verbal reports, was the loggerhead. some places it seemed possible that t name *mestiza* might apply to a fi turtle that would have had to be *C* *etta*, but elsewhere exceptionally lig colored examples of *Chelonia* or *Le* *ochelys* were pointed out by fishernen as being *mestiza*'s. Thus, as I ave said, the sea turtle fauna in the laces visited consists essentially of he two genera, *Chelonia* and *Lepidohelys*. It is with the former that the bservations below are concerned.

We first came upon the black turtle t Kino. sixty-five miles down a newly aved road from Hermosillo. There as a canoe landing on the beach at ino village, and by the landing was thatched, stick-walled pen. In the pen n old man was using a gourd to dip ater from a bucket and wet down a road spread of sea turtles that lay in he shade. The turtles looked familiar, ut somehow a little wrong. They had he smooth. neat, unmistakable heads, ng front flippers, and general air of he green turtles I know from Atlantic egions; but they were off-key in olor. and the shells seemed too deep nd straight-sided. I had just come rom Costa Rica where I had seen a undred or more Caribbean green turles, and these at Kino made me feel nfocused. I asked the old man what ind of turtles they were.

"*Prieta*," he said. "Black turtles."

Most of the turtles were belly down n the sand. but twelve at one end ere back down, in the traditional anner. He said the dozen on their acks had just arrived and were still brave." Right-side-up, they would crawl about and rip out the palisade or cause confusion in the pen. After a day on their backs they became sad, he said. and would lie still. so they could be righted again. When I asked why he poured water on the turtles, he said it was to keep down their fever. When I asked what fever, he said the fever they get when one neglects to pour water on them.

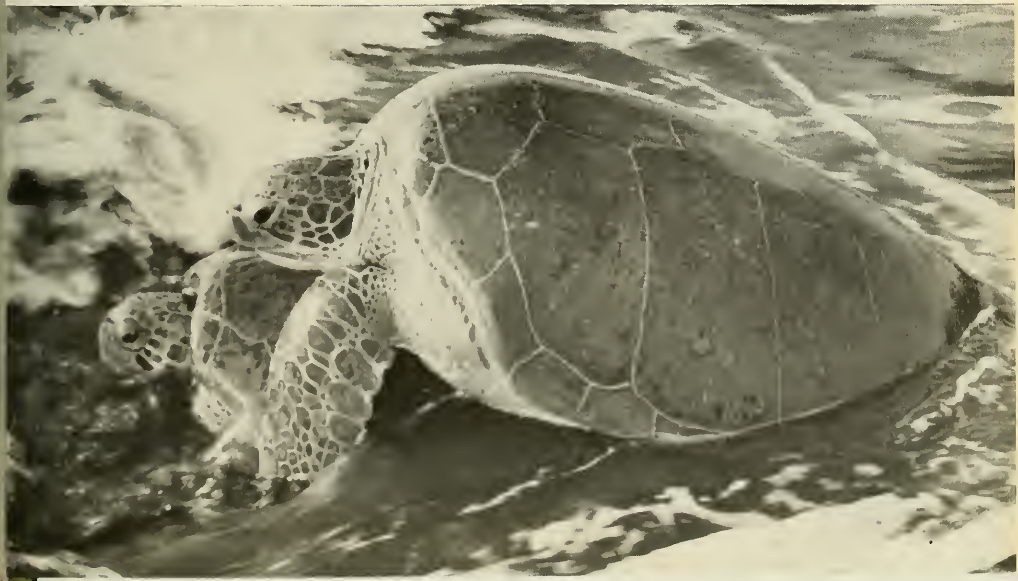
The turtles were being held for the arrival of trucks to take them to Tijuana, Mexicali, and San Diego, where their flesh is highly regarded as a food. They had been brought, and were being added to, by turtle fishermen coming in from little islands between Kino and Tiburon Island, which lies just within sight on a clear day. The turtles had all been harpooned at night on their feeding ground. They can be assumed to have been a typical sample of the population in the area.

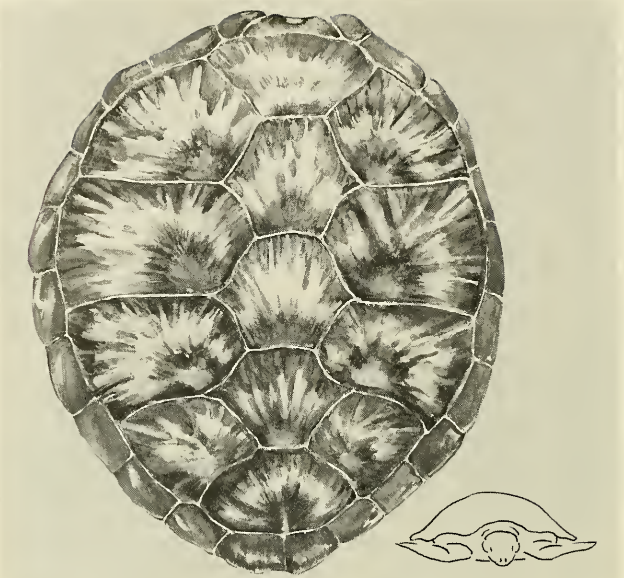
THERE were fifty-three turtles in this lot—forty-nine females and four males. The range in their size was from 17¾ inches to 30½ inches. the average being 23 inches. The largest was a male; the next largest was a female 30¼ inches long. The four males were adolescent, although all showed secondary sex structure, and the largest was evidently close to maturity. Most of the females were below minimum breeding size for the Atlantic green turtle. Their immaturity was borne out by the fact that none had mating scars on the fore-margin of the shell. This was also confirmed by local fishermen, who said that none of the females caught there is ever found to have shelled eggs in the oviduct.

I took a sample of stomach contents from a refuse heap where several of the turtles had been butchered. The sample consisted wholly of two kinds of algae. one called locally *sargasso*, the other *lechuga*. Both turtle fishermen and turtle slaughterers told me that such algae, growing in beds about the islands where the turtles were taken. were almost the only food of local *prieta*. The men apparently knew nothing of any marine spermatophyte plants such as eel-grass, turtle-grass, or manatee-grass, which are the main foods of the Atlantic green turtle.

This sample, then, clearly represented a non-breeding colony similar to that at a comparable latitude on the west coast of peninsular Florida. It was thus no surprise when the keeper of the crawl and other local people spoke of the strong seasonality of the Kino-Tiburon black turtles, because the Florida green turtles are seasonal, too. All reports indicate that the black turtle begins to thin out in October, disappears in late November, is gone throughout the winter, and comes back again in March and April. This

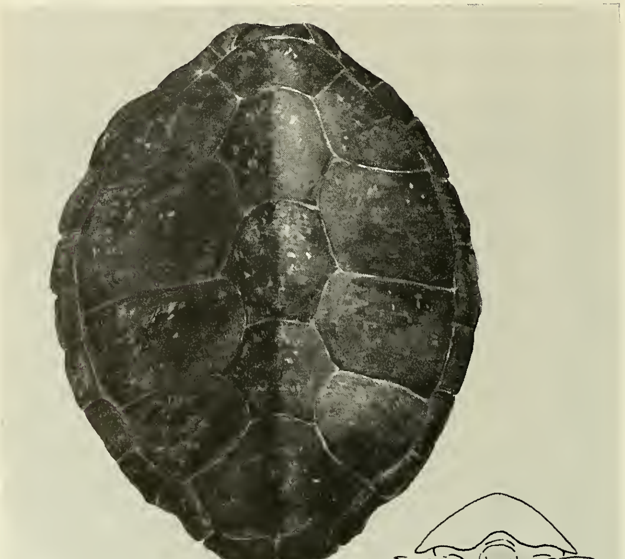
REEN TURTLE, the *Chelonia* of the Caribbean and Gulf of exico, is identified by its sparse dark markings on light ground color that varies from brown to olive. This pair was photographed at Tortuguero, on the coast of Costa Rica.





Typical carapace of Atlantic green turtle, *above*, is slightly curved and has light ground color. When blotched, marks tend to form radiating patterns.

Dark carapace of the Pacific "black" turtle, together with the steep profile of its shell, *below*, distinguish this *Chelonia* from its Atlantic relative.



schedule is strikingly like that on th
turtle-grass flats between the Suwanne
River mouth and Tarpon Springs
Florida, and is what one expects of
colony of young animals, born in som
distant place and destined to retur
there to breed in some future period

The only known center of grou
nesting by Pacific *Chelonia* in Mexic
is considerably farther south—at Mar
uata Bay, on the coast of the State o
Michoacan. This colony has been de
scribed by Dr. James Peters in *Th*
Biologist. It is probably the mai
breeding assemblage for a great ex
tent of the east Pacific shore—possibl
for all that north of Michoacan. Th
more accurate and articulate inform
ants from Kino to the coast of Nayari
agreed that the main nesting ground
of *caguama prieta* or *negra* (*Chelonia*
lay "somewhere to the south."

That the Maruata Bay assemblag
may be unique is also suggested by th
attention given it in the account of th
seventeenth-century explorer Willia
Dampier and that of his mate, Willia
Funnell, writing in the eighteenth ce
tury. I have not yet been able to vis
Maruata. Although Dr. Peters sai
nothing about the coloration or shap
of the shell of the nesting turtles h
observed there, it seems possible th
they may be the parents of the imm
ture black turtles that turn up as sum
mer residents in the Gulf waters.

NOWHERE were there found stage
in weight between the approx
mately 15-pound minimum of th
Kino series, and the hatchlings an
breeding adults at Maruata Bay. Thi
too, brings to mind the situation in th
Caribbean and Gulf of Mexico. Youn
green turtles weighing 10 to 80 poun
are seasonally common in Florid
while only breeding adults and ne
hatchlings are found in Costa Rica
waters. Nothing is known of the fate
the hatchlings or of the origin of th
itinerant Florida population. The pa
allels with the situation on the Pacif
coast suggest that the life cycles of th
two colonies involve similar patter
of developmental migration.

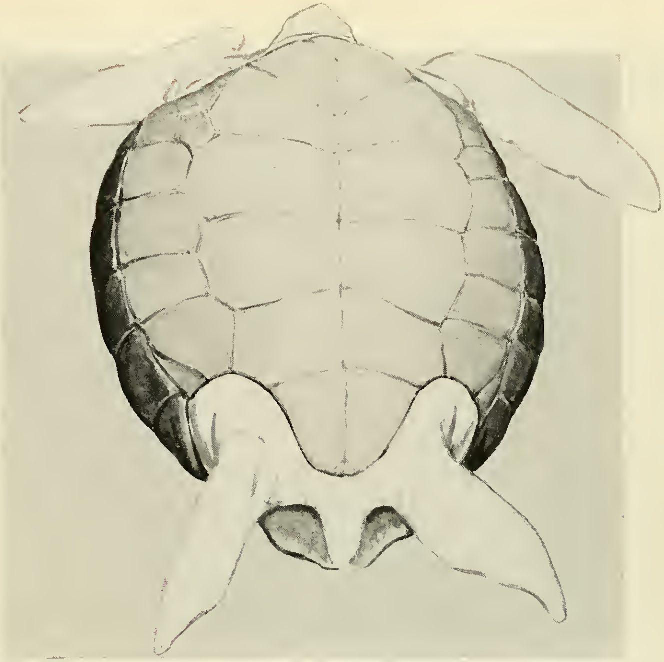
Both the immaturity of the blac
turtles at Kino and the curiously u
balanced sex ratio were duplicate
farther south at Topolobampo, whe
the shells of 115 *Chelonia*, caught ne
the little islands in spectacular Ohu
Bay, were examined. In about a thi
of these, sex could not be determine
in the rest, males made up only 4 or

r cent. Melanism. the pronounced rk pigmentation noted in the Kino rtles, was evident in these also, and e shells of the females had the same ep. flat slope we observed at Kino.

AT Mazatlan, Tamboritos, and Teacapán, no evidence of the occur- nce of the black turtle was found. hough the ridley was obviously mmon. The next appearance of *elonia* on our trip south was at San las where, among numerous shells d bones of ridleys. I found the carace of a single freakish black turtle. idently an adolescent male. It was ½ inches in length, as dark as a no turtle, and peculiar in having five erals—the big scales along either le of the shell—on the left side, and e normal four on the right. Having ard much talk of the *mestiza* here, I rried the carapace and that of a fe- ale ridley to a fisherman who had pressed me as both sensible and fa- liar with the local turtles, and asked m what they were. The ridley he lled *golfina*, and the other, the odd *elonia*, he said was *prieta*. I asked m what sort of turtle *mestiza* was. He arched along the shore among ridley ells. chose one a little lighter in lor than the rest. and told me that s *mestiza*. When I objected that in nora and Sinaloa *mestiza* seemed to the name for a color phase of *pri- a*. the man admitted that the term is sely used. It seems probable, then. at along the Mexican coast the term *stiza*, which means crossbreed. is t restricted to any one kind of turtle t is simply used for any specimen at looks strange or exceptional.

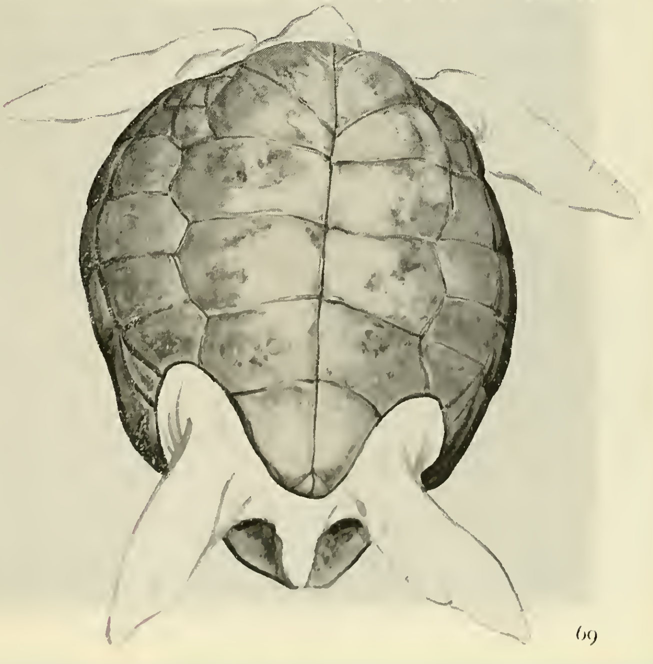
After going home and meditating on e black turtle. I began to see how ntalizingly incomplete the summer's servations were. There was the coast Colima. for instance—a big gap be- teen the southernmost locality I had ited and the one known nesting ound at Maruata Bay. There was also e recurrent talk I had heard of asses of sea turtles round La Paz, nich is in the state of Baja California. the opposite coast of the "Sea of rtes" from that I had visited. I de- led to go back to Mexico to piece out mething more of the story.

At Manzanillo. the chief port of Col- a. only about fifty miles north of e Maruata rookery. fishermen knew e black turtle well. but said they ught it only rarely. The turtle they re bringing to the local market was



TYPICAL PLASTRON of Atlantic green turtle, *above*, is clean greenish white. As with all coloring described, there is much variation among individuals.

PLASTRON of the "black" turtle, *below*, found along Pacific coast of Mexico, is distinguished by blue cast that is caused by deeply placed black pigment.



A University of Florida Professor, DR. CARR is author of many popular and scientific books. The work he relates in this article was supported by funds from the National Science Foundation.

the ridley. My scratching about local dumps and garbage heaps substantiated the word of local turtle experts that, although *prieta* is an occasional visitor there, it is much less abundant at all seasons than the ridley, and never nests on nearby beaches.

FROM Manzanillo I crossed to La Paz. Here the situation proved to be precisely like that at Kino Bay, with black turtles sufficiently common to support a small local fishery, and with the ridley, at least at that season, sparingly represented. The black turtles there graze on beds of algae, and are taken with both harpoons and nets. As at Kino, the colony is made up of young turtles. Of twenty-one that I measured, the range in shell length was from 17 to 32½ inches, with an average of 24¼ inches. The largest specimens of both sexes were apparently not quite mature.

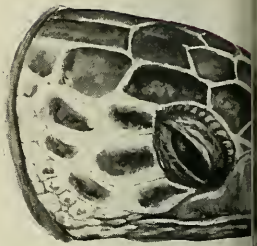
When I asked turtle fishermen about nesting grounds, some looked vague and said, "*¿Quien sabe?*" Others made directionless gestures in the air and said maybe they nest in Sonora or Sinaloa, or in other places in which I was pretty sure they did not.

As on the mainland side of the Gulf, the Baja California turtles are readily distinguishable from Atlantic *Chelonia* on the basis of color and of the shell shape of the nearly grown female. The head and the forelimbs are much darker—often a nearly solid black. The upper shell is either deep black or heavily blotched with separate sooty markings, while the plastron is clouded with deep-seated pigment that shows blue through the horny belly scales. I should say that a complete novice in turtle study would be able to separate 95 to 98 per cent of a mixed lot of *Chelonia* from La Paz and Cedar Key. The confusing ones would be occasional individuals that completely lack the strong pigmentation, and are too small to show the steep shell-sides. It is of interest that on both sides of the Gulf of California these exceptional specimens, which to my eye look like good green turtles, are referred to by some people as *mestiza*'s. Whether they are simply variants that turn up among more typically pigmented brothers and sisters, or are waifs brought in by currents from some distant place, only breeding experiments will be able to reveal.

The green turtle of the Pacific coast of the Americas was first described from Guatemala by the nineteenth-century French zoologist Bocourt, who named the new species *agassizi* in honor of the great American naturalist, Louis Agassiz of Harvard. Bocourt said nothing of his new turtle's being blacker than usual. Through the past twenty years I have seen several dozen Pacific green turtles along the coasts of Central and South America, and while I had previously observed the steep shell of the young female (I illustrated it in my *Handbook of Turtles*), I don't recall having particularly noticed any such heavily pigmented look as the Mexican turtles have. The limits of the territory occupied by *caguama prieta* remain to be determined. Eventually, it must also be known whether its curious coloration is hereditary or is produced directly by some factor in the environment—by the diet of algae, for instance. If the trait is inherited, and if the turtles showing it are confined to the upper Pacific coast of Mexico, there is a good probability that someone will give the population a new scientific name.

ONE of the most interesting aspects of the situation is the way the few known facts seem to fit into a world pattern of sea turtle natural history. So far, only the outlines of the pattern have emerged; but wherever good information is available the indications are that the half-grown *Chelonia* lives in places distant from both the feeding grounds on which the mature turtles spend most of their lives and the beaches to which the females go at three-year (rarely two-year) intervals to nest. Where baby turtles stay during their first year of life nobody knows; and the travels of all stages are almost wholly hidden.

Meanwhile, the most useful result of the recent observations in Mexico is pinning down the common names. The terms are misued here and there; but not often by the real *conocedores*, not by the sound old turtle men. Knowing these names clears the way for more profitable sifting of folk zoology for leads that can be used in locating and separating habitats of the Pacific turtles. With this done, we can then trace their migratory routes and stations.



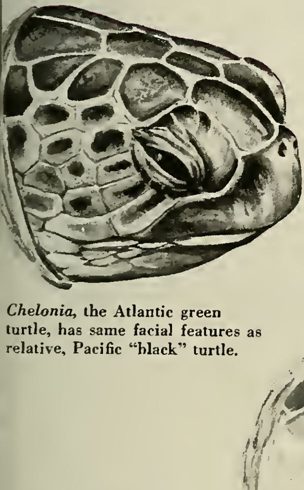
***Eretmochelys*, easily identified by its English common name, ha**
is called *carey* by Mexicans.

These close-ups of five commo
turtles reveal main distinguis
head features. Factors of age and
however, may result in consider
deviation in individuals, so
identification of particular tu
depends on clues other than h

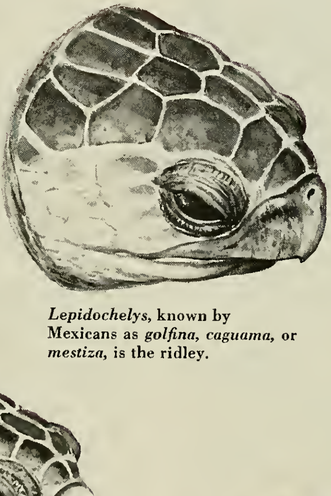
Illustration
MATTHEW KALME

FAMILY CHELONIIDAE

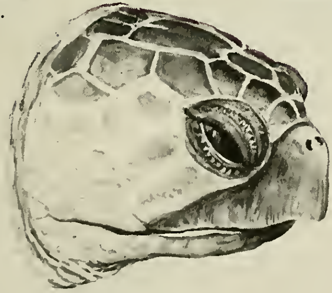
FAMILY DERMOCHELYIDAE



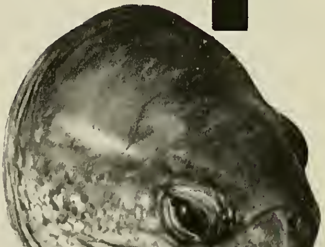
Chelonia, the Atlantic green turtle, has same facial features as relative, Pacific "black" turtle.



Lepidochelys, known by Mexicans as *golfina, caguama,* or *mestiza,* is the ridley.



Caretta, known in English as loggerhead, was only species not found along Pacific coast.



Dermochelys, a straggler along Mexican coast, where it is called *galápago,* is the leatherback in English.

YOUNG SCIENTIST

A study of the role of the pineal system in amphibian behavi

By William M. Adkins III

Extensive research into the nature of the pineal system and its functional significance in animal groups, from lamprey to man, is experiencing a new revival. This tiny series of connected outgrowths from the forebrain (diencephalon) has fascinated men ever since Galen. Speculation as to the nature of the pineal system has passed through several stages. Descartes, for example, thought of the system as the "seat of the soul." Today, the pineal is considered to be tissue of *uncertain* function.

Recently the pineal system in the lower vertebrates—fish, amphibians, and reptiles—has received particular attention. Certain pineal outgrowths in these animals lie under a layer of translucent skin above the brain, or in or beneath a light-transmitting region of the skull. These apparent specializations for light reception suggest a sensory role with respect to solar radiation.

In 1958, Stebbins and Eakin published their studies of the photoreceptive capacity of this "third eye" in reptiles. When the pineal element was removed or shielded in four species of lizards, striking behavioral and metabolic changes were noted. It was found, among other things, that treated lizards spend a greater amount of time in high-intensity illumination and are also poorer at surviving when deprived of food.

This study applies Stebbins and Eakin's general techniques with reptiles to the amphibians, instead. Pineal interference was achieved by blocking the influence of light on this system of brain tissues in two species of the Amphibia: the leopard frog *Rana pipiens* and the southern toad *Bufo terrestris.*

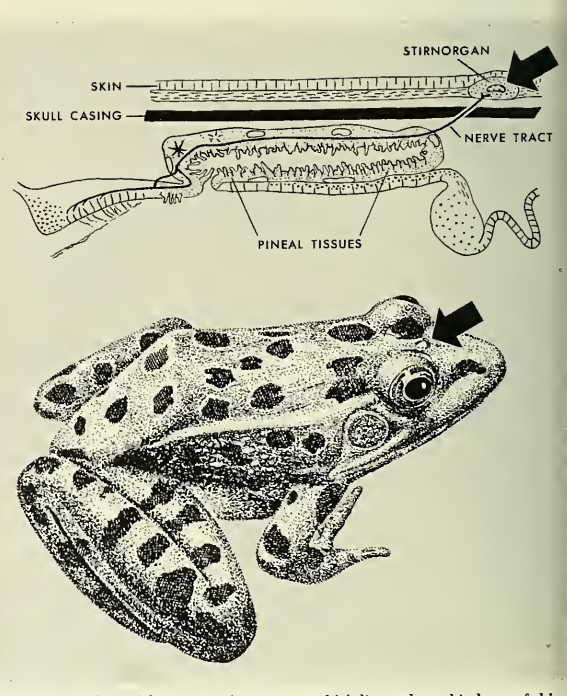
Several fine studies, notably those of Kelly (1960), have been published on the histological and histochemical features of the pineal system in European amphibians. The most conspicuous element of the system is a small saclike piece of tissue, the stirnorgan, which lies beneath a translucent spot in the skin between the eyes. Studies of this element in *Rana pipiens* show it to be connected by a stalk that pierces the skull through a minute opening, drawing at right.

Kelly has shown that such stalks enclose a nerve tract connecting the stirnorgan with the remaining pineal tissues in the skull. Pineal function in the leopard frogs was investigated by means of removing the stirnorgan. This was done by cutting out an area of skin, 2 mm. square, in which the stirnorgan was embedded, from each of the frogs. Within a week, the wounded area had healed. As a matter of control, a 2 mm. square area of skin was removed from the right hind legs of other frogs. Such animals were referred to as "sham-operated."

In southern toads, all pineal elements are evidently positioned *within* the skull casing, no stirnorgan being present. Any solar radiation that might affect this pineal system would have to penetrate both the skin and the brain casing.

Since surgical removal of any portion of the pineal in the toads might cause damage to the brain, an alternative method of study was devised. Petrolatum (as a skin protector) was smeared over the skull between and on the cra crests. Then a non-drying putty c pound was pressed on the skull in s a way that no light could enter betw this putty shielding and the skin. A cation of the putty had no apparen ritating effect on the molting cycle the shielded toads and, for this rea no sham-operation was conducted the control toads.

Rana pipiens were obtained from kosh, Wisconsin, where they were lected during the fall months and st in spring-water holding pens. Upon rival at the laboratory, they were ei immediately put into an experime run or stored in a refrigerator at 10 until needed. *Bufo terrestris* were lected from fields in the Melbou Florida, area during heavy "hurric



Stirnorgan, indicated by arrows, is most conspicuous part of frog's pineal system, which lies under a thin layer of skin a brain in light-transmitting region of s

In March of this year, seventeen-year-old William M. Adkins III, of Melbourne, Florida, placed third among 4,000 high school seniors in the Westinghouse Science Talent Search. Part of his prize-winning study is on these pages. Mr. Adkins will use his $5,000 scholarship to study at Harvard. His paper is followed by a commentary on the work and its importance, written by Dr. Richard G. Zweifel, Associate Curator of Herpetology at The American Museum of Natural History.

ins in late October and stored until the me of experimentation.

T is believed that much experimental work on pineal function has failed yield noticeable results because of the perimenters' efforts to maintain uni- rmity in the environment. In the lower rtebrates, metabolic activity is con- olled and maintained by movements to id from certain intensities of light and mperature and areas of varying water ntent. It seemed especially important, erefore, that a wide spectrum of en- ronmental conditions—to or beyond e upper and lower extremes of toler- ice—be available. Then the effect of neal interference might appear as an tered behavioral pattern.

Using this approach to the problem, indoor environmental gradient cham- r, 3 feet by 6 feet in size, was con- ived that allowed the leopard frogs to ek three moisture situations (water, oist sand, and dry sand) extending rough three areas of light intensity: ep shade, weak shade, and full light age 74). This chamber was built in a ntrolled-temperature room, where the mperature through the chamber could maintained within 2° C. (Mean air mperatures were: 25.2° C. in full light; .1° C. in weak shade; and 24.3° C. in ep shade. Mean water temperature is 23.5°C.)

Open-end cardboard boxes were anted in each lighted area of the sand- led runways, providing corners and rfaces with which the frogs could come close contact. Observations were made this thigmotactic behavior, as well as light and soil moisture preferences. total of 494 observations were made 4 normal control, 17 operated, and 10 am-operated frogs.

A similar, but smaller gradient cham- r (2 feet by 3 feet) was used to study e behavior of the toads. This chamber ovided for four moisture variations— iter, soggy sand, moist sand, and dry nd—traversing a three-divisional adient of light and temperature (from ° C. in the deep-shaded area to 26° C. the fully lighted area). Records were ken of the toads' preferences for light d soil moisture, and of general skin gmentation. Both shielded and control ds were studied for 20-day periods in perimental runs accommodating four ds. Four runs were conducted, two of which yielded sufficient data on the effects of shielding on behavior.

Response to Light and Soil Moisture

The behavioral responses of the leopard frogs to light and soil moisture were observed by lifting a black drop canvas on an open side of the chamber and recording the position of each frog by scoring each one with the following point systems:

Light Exposure Index

POINTS	POSITION OF FROG
1	Exposed in deep shade
2	Exposed in weak shade
3	Exposed in full light

Water Metabolic Index

POINTS	POSITION OF FROG
1	Immersed in water
2	Resting on moist sand
3	Resting on dry sand

All data were analyzed on a group basis and treated in two ways. The first 100 observations of light exposure and water metabolic indexes were summed up for each run, so that a simple statistical analysis might be applied. The light exposure and water metabolism indexes of normal control and sham-operated runs were totaled; those of the operated runs were summed up. It was supposed that if frogs have no preference for any light intensity, they will spend equal amounts of time in each light area of the chamber and receive 400 points, as a group, in 200 observations. The control group received 375 points, deviating by 25 points from the expected 400. The operated group totaled 481 points, deviating by 81 from the 400 expectancy.

Removal of the stirnorgan thus appears to have a significant effect on the preference for light intensity, leading these frogs to spend more time under bright illumination. In comparison, no significant difference appears between the water metabolic indexes of sham-operated and stirnorganectomized frogs.

A computation of the percentage of time spent in all areas of light intensity and soil moisture of the chamber indicates that stirnorganectomized frogs make greater use of bright light than the sham-operated frogs.

With the gradient chamber of four soil moisture runways, a different set of

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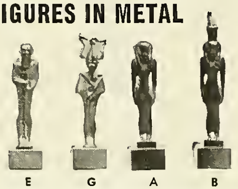
FIGURES IN METAL



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point systems was used to study the behavior of the southern toad. The light exposure index considered the characteristic burrowing behavior of the toad:

Light Exposure Index

POINTS	POSITION OF TOAD
0	Completely burrowed in deep shade, weak shade, or full light, or head protruding from deep-shaded burrow
1	Completely exposed in deep shade, or head protruding from weak-shaded burrow
2	Completely exposed in weak shade, or head protruding from full-lighted burrow
3	Completely exposed in full light

Water Metabolic Index

POINTS	POSITION OF TOAD
0	Immersed in water
1	Resting on soggy sand
2	Resting on moist sand
3	Resting on dry sand

Shielded toads tended toward higher light and temperature intensities and a drier substratum, although no significant differences in the total light exposure or water metabolism points of shielded and control toads were apparent.

Thigmotactic Response

OBSERVATIONS were also made of the percentage of time spent by the leopard frogs in contact with objects and with other frogs and the effect of the stirnorgan's removal on this thigmotactic response. Operated frogs appeared to spend greater time in "huddles" and close contact with each other than did sham-operated and control toads. No exceptional differentials showed up in contacts with inanimate objects.

Pigmentary Responses

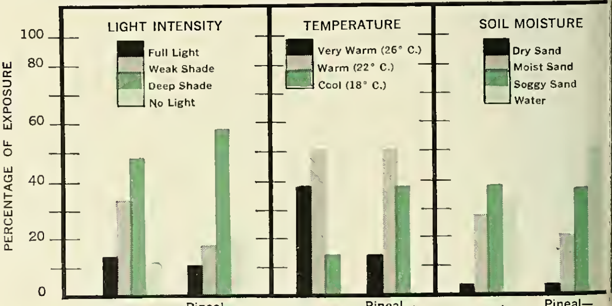
RESPONSES of the skin pigmentation to pineal interference could not be easily studied in the frog experimental runs. These responses were recorded for the toads, however, using a three-point system: 1, light; 2, medium; and 3, dark. Pigmentation points received by control and pineal-shielded toads suggest that
interference of the pineal induc
blanching of skin pigment cells and ge
eral paling of the integument.

A different experiment was designe
to study the effects of stirnorgan r
moval on pigmentation in frogs kept
continuous light or darkness. Four ope
ated and four sham-operated frogs we
placed in a lighted aquarium (mea
temperature: 24.5° C.). Three operat
and five sham-operated frogs we
placed in an aquarium in a complete
dark incubator (mean temperatur
23.5° C.). The same three-point syste
used for the toads was applied to the
frogs. Records were taken daily. At 1
18. and 23 days. mean points receiv
per individual in each group were co
puted. and differentials between operat
and sham-operated frogs estimated.

As expected. frogs in continuous dar
ness were darker than those in contin
ous light. In both light and dark grou
the operated frogs were somewh
lighter than sham-operated frogs,
though there was a lesser differential
the dark group. In the dark group, th
differential consistently decreased wi
the number of days of exposure; in t
light groups, it increased with the nu
ber of days. On the basis of these fin
ings, there is strong reason to belie
that the stirnorgan plays a role as a *lig*
receptor and a mediator between the e
ternal lighting conditions and the pi
mentary system of Amphibia.

Sensitivity to the Observer

ONE of the interesting behavioral p
terns observed by Stebbins a
Eakin (1958) in parietalectomized l
ards was their lack of response to t
observer at the time of observation. A
though no records were made during t
four runs on *Rana pipiens*, casual obs
vations were consistent with those
lizards: only those foreign sounds a
movements of a high intensity proved
scare or activate the indifferent stirn
ganectomized frogs. Sham-operated fro
were of a more sensitive nature. a



RESPONSES of *Bufo terrestris* to various conditions of light, temperature, and soil moisture indicate that shielded toads te
to higher light and temperature intensiti

greater care was required to avoid frightening them while the various records were being taken.

Water Metabolic Rates

An interest in the rates of water upake and water loss through the skin of *Bufo terrestris* brought about a study of hese rates in individual toads following pineal-shielding. Trends. although not significant, appear to suggest that pineal-shielded toads exhibit a slower rate of water loss and a faster rate of water uptake than usual.

It is interesting to note one occurrence hat was observed following pineal nterference in *Bufo terrestris*. Pineal-hielded and control toads were divided nto two groups, one being placed in continuous light, and the other in coninuous darkness. This was a pilot run at long-range pineal-shielding, and a porion of the toads was sacrificed every week for a one-month period. During the atter part of this experiment (with only 1 toads remaining), neglect to refill he aquaria with water produced desicating conditions for a span of time during which 30 to 40 per cent of the body weight of a toad could be lost. It was found that five of the six pineal-hielded toads had reached the intolerble limit of their water loss and did ot survive the exsiccation; however, all ve of the control toads survived and ppeared in "good condition."

Summary

1. Both operated frogs and shielded toads consistently make greater use of igh-intensity light, and trends indicate reater use of a drier substratum.

2. Operated frogs spent a greater perentage of time in thigmotactic response ith other frogs. Casual observations lso indicated that they are less sensitive nd less liable to retreat in response to xcessive agitation in the form of movements and sounds by observers.

3. Shielded toads are somewhat lighter n skin pigmentation than are unshielded (control) toads. In a different experiment with frogs, a paler condition of the kin follows with operated frogs kept in continuous light (but *not* in continuous arkness) for 23 days.

4. As in lizards, the pineal system appears to regulate the metabolic activity f amphibians by responding to light nd influencing their behavorial patterns. It is belived that normal functionng of the pineal in response to light is ecessary for the survival and well-being f the frogs and toads studied, apparntly because a functioning pineal sysem prevents a more rapid exhaustion of nergy reserves. As a homeostatic mechanism, the pineal system of amphibians eeps metabolic activities within certain imits by influencing the animals' basic ehavorial patterns.

COMMENTARY

Experiments of the kind performed by Mr. Adkins hold a special fascination, for they cut across disciplinary boundaries and appeal to persons working in a variety of biological fields. Thus, the present study has implications for habitat selection that will gain the attention of the ecologist. The student of animal behavior will also find material of interest here, as will the physiologist and the physiological ecologist.

The Adkins experiments have the virtue of simplicity; another worker with relatively limited resources could easily repeat the work on the same or other species. But an uncomplicated approach does not necessarily go hand-in-hand with uncomplicated and easily interpreted results. Here we find data on behavioral and pigmentary response to light, choice of moisture conditions, thigmotactic responses, and reaction to outside disturbances, all as related to the intactness—or absence of shielding—of the pineal organ.

The pioneering aspects of this initial work on frogs and toads necessitates that comparisons be made with unrelated forms, so the apparently parallel results found between such different animals as these frogs and the lizards studied by other workers are of particular interest. A lizard that basks in the sun and a frog that is largely nocturnal both respond to removal of the stirnorgan by increasing their exposure to light. Yet investigation of the lizard-like tuatara of New Zealand (a reptile only distantly related to lizards), studied after Mr. Adkins did his research, revealed that this animal made no behavioral response to interference with its parietal eye. Removal of the stirnorgan of tadpoles has likewise produced no positive results. Perhaps the only possible prediction is that the results of any new experiment on the pineal system are unpredictable. Indeed, the stirnorgan of frogs and the parietal eye of lizards may not even be homologous structures, and we may in effect be comparing apples and turnips.

The observations on reactions to outside disturbances again are parallel in lizards and frogs, the operated animals being less shy. But Adkins' suggestion that the frogs are responding to sound should be documented carefully, for many observers have noted that frogs (with the exception of females seeking their croaking mates) are notoriously unresponsive to sounds. The piercing "fright scream" of a leopard frog seized by a predator, a horrid sound to human ears, produces no grossly visible response in other frogs.

The behavior of strinorgan-less (or parietal shielded) frogs and toads is altered rather subtly, if indeed it is altered at all. Hence, if normal variation

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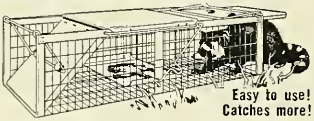
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in behavior is to be distinguished fro
true changes induced by the experi
mental conditions, it is important tha
experiments be performed on a larg
number of animals. In future exper
ments, Mr. Adkins and his successor
should utilize larger numbers of animal
and determine whether factors such a
sex, breeding condition, and body siz
(or age) influence behavior patterns.

Other possible angles in future stud
suggest themselves. For example, th
study of internal physiological rhythm
in animals is currently attracting the a
tention of many workers. We may wo
der, for example, if the toads would hav
been found behaving in the same fashio
if observed at 10:30 P.M. and 2:30 A.M
instead of during daylight hours.

WHENEVER possible, different specie
undergoing test should be expose
to the same experimental conditions, s
that comparisons between the specie
can safely be made. In the present stud
the toads were exposed to a combine
light and heat gradient, but the frog
were subjected to relatively little ten
perature variation throughout their e
perimental chamber. As a result, w
cannot directly compare the results
the two experiments. The more simp
experimental conditions may in part e
plain the positive results obtained in th
frog experiment.

One might object that the toad, lac
ing a stirnorgan, would be unlikely
respond as does the frog, but Adkins r
ports that both toads and frogs respon
to stirnorganectomy (or shielding of th
parietal region) by adopting paler pi
mentation than do unmodified animal
and he goes on to relate the state of pi
mentation to illumination.

In demonstrating a definite relatio
ship between the pineal system and lig
in the leopard frog and southern toa
Mr. Adkins has made a unique and va
uable contribution. Because the field
research into which he has probed is
most difficult one, both his initiative an
his energetic and thoughtful work a
the more to be commended. We trust h
experience in this initial study will e
courage Mr. Adkins to further researc

RICHARD G. ZWEIF

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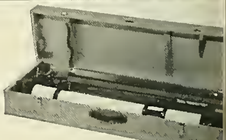

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Natural History

Incorporating Nature Magazine

Here a group of 50 barrel assemblies is being readied for completion by our Mr. Ernest Arndt. Each barrel consists of 23 parts. The largest piece is an aluminum forging with thin walls and a thick bottom. We send groups of the tall cups or shells to a man named Gerald Fegley, who chose to make parts for Questar in his own shop rather than be superintendent in the die shop of a great die-casting firm. With the engine lathe, Mr. Fegley turns off and discards the forging's entire thick bottom, which exists only to leave enough metal on the inside of the tube to permit him to cut big husky threads. After so doing, he shortens the tube and reduces its outside diameter on the lathe. Mr. Fegley then ships these precisely machined-all-over tubes to a painting specialist, who masks off the large internal threads and the cell seat at the opposite end, then sprays the inside with a newly developed nonreflective paint.

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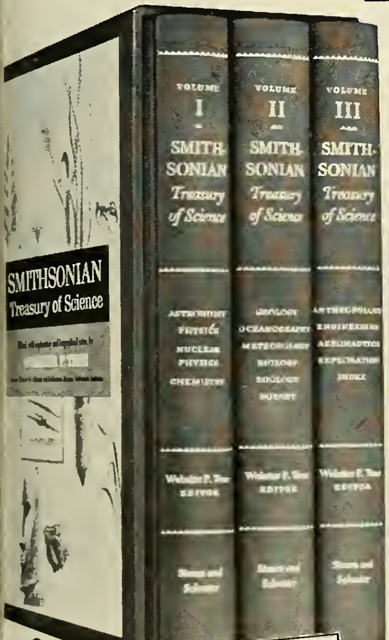
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THE JOURNAL OF THE AMERICAN MUSEUM OF NATURAL HISTORY

Vol. LXX NOVEMBER 1961 No. 9

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COVER: Seen here is a commonplace but remarkable animal—the starfish. Th photograph shows part of the ventral surface of the creature's arms, from whic the tube feet project in double rows. In his article, which begins on page 10 Dr. Allison Burnett, of Western Reserve University in Ohio, discusses th complex anatomy of the starfish. Dr. Charles Walcott, of Harvard University made the photographs that illustrate the text in a salt-water aquarium at th Smith School, Lincoln. Mass. Drs. Burnett and Walcott have teamed up befor on these pages, in an article on the hydra (Natural History, November, 1959)

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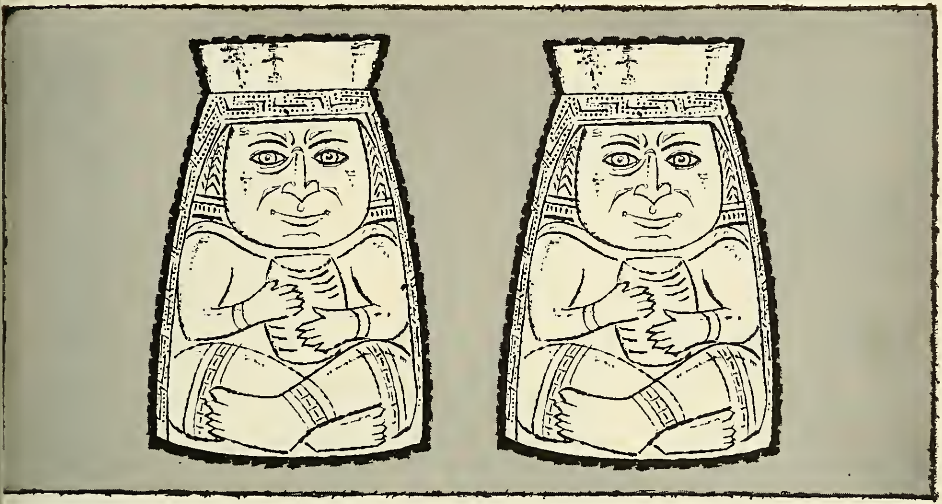


Which twin is the phony?

Lima, Peru, silversmiths use ancient ethods to reproduce priceless mu- eum pieces or create modern silver ervices at a fraction of U.S. prices. .S. Fur rugs and antiques are also argains in Peru.

the anthropomorphic Mochican jug the left were for sale at all, Lima's ca Museum would ask four figures...

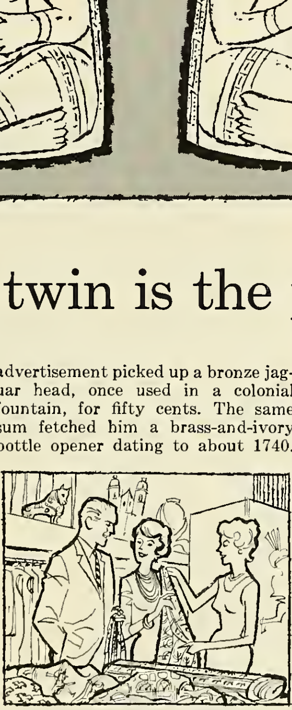
Its exact duplicate, to the right, as made by descendants of the Mochi- ns, using the same sterling silver, d working in the same hallowed chniques. It is only a "phony" in the nse of being new. You can buy it, or e like it, for about $8.50 on the venida Jirón de la Unión. It is about ven inches high.

Colonial relics

isitors to this charming City of the ings call it one of the world's great opping centers, particularly if you n spot value in art and antiques.

Charming paintings of saints and e old Conquistadores can be found r a dollar or so in shops surrounding e Cathedral, on Avenida Jirón, and ar the Plaza de Armas. Cherubs in lt gesso, mirrors with fine old silver ames, and portraits of forgotten an- stors are also easy to find, and expensive.

Last January the writer of this advertisement picked up a bronze jaguar head, once used in a colonial fountain, for fifty cents. The same sum fetched him a brass-and-ivory bottle opener dating to about 1740.



Both came from a restaurant where they were part of the décor, and in which all the charcoal-broiled chicken you can eat is yours for about $1.00.

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If you are not an *aficionado* of antiques, Lima's shops can make your mouth water with bargains in modern silver, too. A six-piece tea and coffee service, in a traditional pattern, can be had for as little as $95—or less than half what you'd pay in the U.S. Silver pitchers also merit attention.

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INDIANS of NORTH
INDIAN LIFE

Reviews

The American Indian in current books

By John C. Ewers

Indians of North America, by Harold E. Driver. *Univ. of Chicago Press, $10.95; 667 pp.* American Indians, by William T. Hagan. *Univ. of Chicago Press, $4.50; 190 pp.* Indian Life in the Upper Great Lakes, by George I. Quimby. *Univ. of Chicago Press, $5.95; 208 pp., illus.* The Indians of Texas, by W. W. Newcomb, Jr. *Univ. of Texas Press, $5.75; 404 pp.* The Assiniboines, by James Larpenteur Long. *Univ. of Oklahoma Press, $5.00; 209 pp., illus.* Spotted Tail's Folk, by George E. Hyde. *Univ. of Oklahoma Press, $5.00; 329 pp.* Mountain Wolf Woman, edited by Nancy O. Lurie. *Univ. of Michigan Press, $4.95; 142 pp.* Indian Art in America, by Frederick J. Dockstader. *N. Y. Graphic Soc., $25.00; 224 pp., illus.*

The needs of the North American Indians, as outlined by their representatives during a conference last summer at the University of Chicago, have received much interest in the last year. Now, on the "Frontier of the 1960's," there are healthy signs that more and more Indians, disturbed by stereotyped and inane misrepresentations of their people, are appraising the current condition of their culture and Indian–white relations. Echoing the interest of the Indians themselves, books published in 1961 show a remarkable variety of attractive and informative works on Indian history, lore, art, and general culture.

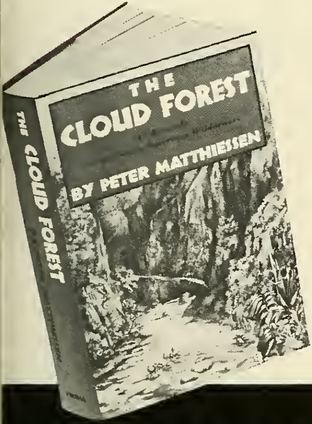
At the same time, many non-Indian Americans, stimulated by scouting and camping programs, by visits to museums, and by travels in our own country, are rediscovering the Indians. These initiates are becoming more aware of the rich contributions Indians have made to our American heritage, and they are recognizing that Indians have been, are, and will remain a significant part of our national folk tradition. However, the very abundance of books on Indians is perplexing to anyone seeking a reliable picture of these people. A recent bibliography of writings on the North American Indians, of particular value to anthropologists and historians, lists more than 17,000 titles, and there must be thousands of other highly colored, romantic, or superficial books and articles that have been written for popular consumption. The interested layman sorely needs a guide to help him to select books that are both readable and worth reading.

Probably the greatest need is for a single volume providing a comprehensive, factual introduction to the historic Indian tribes and cultures of North America. As early as 1917, Clark Wissler, then Curator of Anthropology at the American Museum of Natural History, published *The American Indian*, a general introduction to the Indians of North and South America. Long regarded as a classic in its field, this volume was revised and reprinted in 1922 and again in 1938. But so rapidly have new technical studies in this field been published in recent years that Wissler's book is out of date.

Harold E. Driver's *Indians of North America* is a worthy successor to Wissler's classic, insofar as the Indians of North America are concerned. It is a systematic, sound description of the ways in which the Indians lived before their traditional customs were altered greatly through contacts with European civilization. As did Wissler before him, Driver has grouped the hundreds of tribes by culture areas to facilitate description and to demonstrate clearly the ingenuity of the Indians in making use of the resources of different environments. Early chapters in this book tell of the origin of the Indians, comparing the ways in which the historic tribes of fourteen culture areas made their living. Descriptions of primitive Indian methods of raising crops and of Indian hunting techniques comprise some of the most fascinating sections of this very informative book. Later chapters deal with Indian housing, clothing, arts and crafts, music, trade and transportation, property, marriage and family life, government, warfare, education, and religion. (In virtually all of these aspects of life, incidentally, the achievements of the high cultures of Meso-America contrast sharply with the more modest ones of the Indians who lived north of Mexico.) The concluding chapter impressively summarizes the Indians' contributions to world culture, emphasizing the fact that nearly half of the modern world's foo supply is obtained from plants that wer first domesticated by the American Indians. Carefully prepared maps graphically portray the locations of cultur areas, the natural vegetation areas of th continent, the relative density of India population, the distribution of India languages, the dominant types of subsistence, and the distribution of particular traits of material and social culture such as the cultivation of maize and cotton, the use of alcoholic beverages, hous types, clothing materials, use of weavin devices, pottery-making and method of tracing family descent. A large end-pocket map names and locates al the historic North American tribes

Taking up the Indians' story wher Dr. Driver has left off, William T Hagan's *American Indians* traces th history of Indian–white relations in thi country from early colonial times to th present, particularly emphasizing thei effects upon the Indians. His portraya of the transformation of tribe after trib of courageous, independent red men int depressed, dependent reservation dwellers does not make a pretty story Throughout the long period of the "winning of the West," land-hungry frontiersmen justified their seizure of India lands with the pious declaration tha God and nature did not intend that s much fine land should be monopolize by savages who were incapable of developing it. In the bloody business of advancing the frontier, white men ofte failed to discriminate between friendl and hostile Indians, while the retreatin Indians were unable to forget their sti older intertribal differences long enoug to present a united front against th white intruders. In the Colonial Wa Indians fought the white man's battle on both sides, while in subsequent conflicts Indians aided the whites in fightin neighboring tribes who had long tormented them. Able chiefs led hostil tribes to dramatic victories over th white man. but they could only delay th inevitable conquest.

Once the Indians were pacified. th Government set to work to remake the



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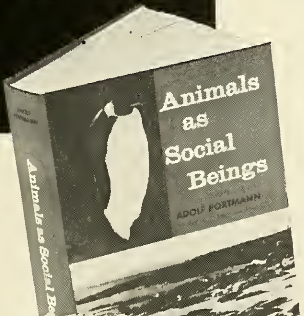

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by Adolf Portmann

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—HAROLD NICOLSON, *London Observer*

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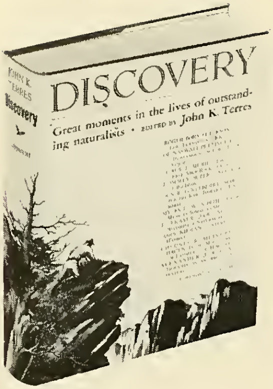
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in the white man's image, prohibiting traditional religious ceremonies, urging the Indians to worship, dress, and work like white men, sending their children to school, and dividing their tribally owned lands into individually owned allotments. Paternalistic policy-makers thought they knew what was best for the Indians, who had no voice in Indian affairs. While the Indians' numbers grew rapidly during the first three decades of this century, their lands continued to slip away into white ownership. The Indians remained apathetic, impoverished, and stubbornly resistant to the white man's efforts to assimilate them into his culture.

By the late twenties it was becoming apparent to students of Indian affairs that doing the Indians' thinking for them was not getting results. Then, in 1934, an Indian Reorganization Act initiated a new policy. The Indians' right to retain their traditional customs was recognized. Indian tribes were encouraged to organize and to engage actively in the management of their own affairs. After generations of being told what to do, it required time for Indians to become accustomed to thinking for themselves, but the new policy stimulated Indian initiative. However, of recent years progress has not been rapid enough to please some non-Indians eager to push the Indians out into the main stream of American life. Other students of the Indian problem think the Indians are not yet ready for such a perilous adventure. Dr. Hagan clearly and calmly describes the issues without taking sides in this present controversy. His book provides a background that will help thinking Americans to form their own opinions of any solutions that are proposed for the complex Indian problem.

George Irving Quimby's *Indian Life in the Upper Great Lakes* traces the Indian occupation, from about 11,000 B.C. to A.D. 1800, of the more than 200,000 square mile area that includes the drainage basins of Lake Superior, Lake Huron, and Lake Michigan. After the glaciers retreated, shaggy mammoths and mastodons moved in, and the Indians who followed them and killed them with stone-pointed spears were the first humans known to have lived in this region. They were succeeded by hunters who made woodworking tools of ground stone and by Indians who fashioned tools and weapons of copper and hunted elk and barren-ground caribou. These Old Copper Indians, who may have lived as early as six or seven thousand years ago, may have been the world's first fabricators of metal tools and weapons. Indians of the Early Woodland Culture, during the period 500 to 100 B.C., were the first of the Upper Lakes people to build mounds of earth over their dead, and the first to make pottery. Then Indians of the Hopewell Culture moved in from the south. They introduced agriculture int this northern region, built more elaborate earthworks, excelled as artists an craftsmen, and traded widely with distant tribes. During the period A.D. 80 to 1600 a great differentiation of cultural groups took place in this region leading to the development of the Indian tribes met by the early Europea explorers of the western Great Lakes–the Miami, Sauk, Fox, Potawatomi, Ottawa, Huron, Chippewa, Menomini, an Winnebago. The last third of Quimby' book describes the aboriginal custom of these historic tribes, the change wrought by the introduction of usefu European-made objects in the earl years of the fur trade, and the breakdown of traditional ways of life amon these tribes under the impact of the advancing frontier of white settlement This full account of more than 12,00 years of Indian life in the upper Middl West is told with that disarming simplicity found only in the writings of scholar who has mastered his subject s thoroughly that he can tell it to the layman without complicating the narrativ by technical jargon. Carefully draw maps, sharp photographs, and drawing of the artifacts typical of each prehistoric culture, as well as reproduction of drawings of Indian life in the earl historic period by contemporary artist add greatly to the reader's enjoyment

MR. EWERS, assistant director of the Museum of History and Technology in Washington, is a specialist in the culture of North American Indians.

ANOTHER well-written regional account is W. W. Newcomb, Jr.'s *Th Indians of Texas*. Although the prehistory of the vast state of Texas is les well known than that of the Upper Grea Lakes, it is clear that Indians hunted now extinct elephant on the Stake Plains more than 12,000 years ag Among other fascinating prehistori finds in Texas are the remains of woman, popularly referred to as "Midland Minnie," whose true age is questionable but may be well into the thousands of years. Within the ramblin boundaries of this huge state, Indians o four different cultural traditions reside in historic times. The warlike Comanch and neighboring, buffalo-hunting horsemen of the Plains, who moved southwar into Texas in the eighteenth century need little introduction to most Texan and to many other Americans. But man other Texas tribes are little-known sav to a few students. Among them were th Karankawas of the Gulf coast and th Coahuiltecan tribes of south Texas. Th latter eked out an existence in an ari land by devouring almost everything i their environment that the human orgar ism could digest—fish, cactus, fruits, mesquite beans, ant eggs, deer dung, and even human flesh. The Jumanos and related tribes along the Rio Grande were little-known gardeners whose cultural affiliations were with the Pueblo Indians of the southwest; while in east Texas the Indians of the populous Caddo confederacies, the most advanced of the Texas tribes, were highly successful agriculturalists who also built temples as centers for complex religious ceremonies.

Newcomb's well-organized book suggests the origins, describes the customs, and traces the history of each of these diverse cultural groups. Time has dealt harshly with the Texas Indians: many tribes have become extinct, while others found refuge outside this state. Not a single Indian tribe remains within the vast area of our second largest state.

The Assiniboines, by James Larpenteur Long, is of particular interest because both author and illustrator were Assiniboine Indians. Mr. Long, a grandson of a fur trader, Charles Larpenteur, and an Assiniboine woman, gathered his information in the native tongue through extended conversations with aged Assiniboines who had vivid recollections of tribal life in buffalo days. In simple, straightforward language Long tells of the traditional customs of his people—how they hunted buffalo, moved camp, warred upon enemy tribes, made pipes, beadwork, and other artifacts, played games, treated the sick, and performed social dances and religious ceremonies. Many interesting details of old-time Assiniboine life not reported elsewhere are given in this book, and some of the major points are illustrated by short, telling reminiscences of older Indians. The Assiniboines, one of the largest tribes of the northern plains, were a conservative people, the poor relations of the mighty Sioux. They owned few horses and continued to practice some of the customs of prehorse days long after their wealthier neighbors had abandoned them. Although the author does not emphasize this point directly, his information tends to support it. He shows the survival of their custom of buffalo-hunting on foot, their heavy reliance upon dogs for transporting camp equipment, and their public recognition of young men who were swift, long-winded runners.

This book should appeal to older children as well as to adults. It is cleverly illustrated by line drawings, executed with a touch of humor by William Standing, a young Assiniboine artist, whose promising career was cut short when he died in an automobile accident.

ONE of the most important, but least known, tribes among the powerful western Sioux, the Brulé, now has its dramatic history told in George E. Hyde's *Spotted Tail's Folk*. Hyde con-

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centrates upon the difficult period of Brulé transition from a free, nomadic, buffalo-hunting economy, to a sedentary, reservation existence in which these discouraged Indians became dependent upon Government rations for their daily bread. Throughout this period their principal chief, Spotted Tail, a man of strong convictions, played a dominant role. Spotted Tail sought to avoid war with the whites, but he refused to accept alien economic and social programs that white administrators sought to impose upon his people. He opposed efforts to make farmers of the Sioux, to convert them to Christianity, and to send Sioux children to the far-off Carlisle Indian School to be educated in the white man's ways. In so doing Spotted Tail gained the enmity of many strong-willed whites and of younger Indians of his own tribe who favored the white man's programs. The internal struggle that ensued between conservative and progressive elements among the Brulé Sioux resembled similar conflicts on other Plains Indian reservations during this same difficult transition period. Hyde's book provides a powerful case history of this conflict. Spotted Tail emerges as a conservative leader of integrity and ability whose influence among his people survived his cold-blooded murder by one of his younger and more "progressive" rivals. The Spotted Tail of this sympathetic story deserves recognition as one of the great Indian chiefs in American history.

Mountain Wolf Woman, is one of the most unusual Indian books of the year—the autobiography of a charming, outgoing, 74-year-old Winnebago Indian woman, as it was tape-recorded at the request of her adopted niece, the anthropologist Nancy O. Lurie. Far too little attention has been given to the roles played by valiant Indian women during the long and difficult period of family readjustment to markedly changed conditions of life in a dominantly white man's world. Men, deprived of their traditional roles of hunters and warriors, were easily discouraged and frustrated. But Indian women, by carrying on their age-old routines as wives, mothers, and homemakers, provided that continuity needed to enable their families to survive. Mountain Wolf Woman was such a woman. With good humor and no bitterness she recalls her experiences in the changing culture of her tribe. Born in 1884, when the Winnebago could still make a living by hunting and gathering wild roots and berries, she early learned to help her mother with the household chores. Her education at a mission school was abruptly ended in the sixth grade when her older brother insisted that she marry a total stranger who had done him a very minor favor. Mountain Wolf Woman's description of her Indian-style wedding to this unknown and unloved man is one of the highlights of her story. She goes on to relate her memories of a later and more successful marriage, her vivid religious experiences as a participant in the peyote cult, and her pride in her children and grandchildren. This simple life-story of a Woodland Indian woman is a rich, human document. Dr. Lurie's introduction, describing how the story came to be told, and her explanatory notes on the old Winnebago lady's reminiscences make this book doubly interesting to all those readers who are not familiar with the customs of the Winnebago Indians.

SURELY the handsomest Indian book of this or any previous year is Frederick J. Dockstader's *Indian Art in America*. It presents 250 technically superb photographs of carefully selected examples of the arts and crafts of the prehistoric and historic Indians of America north of Mexico. Seventy plates are in magnificent color. Each object is briefly identified by size, approximate date, and locality or tribe of origin; its function (if known) is also described. Most of these masterpieces of Indian workmanship are from the collections of the Museum of the American Indian, Heye

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Foundation. in New York City. of which Dr. Dockstader is the Director. Together these specimens illustrate Indian achievement in such varied techniques as wood-. stone-, and ivory-carving; modeled and/or painted pottery; painting on wood, hide, and paper; basketry, textiles, silverwork; embroidery in porcupine quills, moose hair, and trade beads. The number and variety of works depicted—few have been pictured before—are sufficient to demonstrate the wide range of regional styles in Indian arts and crafts. Especially rich is the portrayal of carved and painted masks and other examples of the woodworking skills of the Indians of the Northwest coast, who created one of the world's original art styles. One of the most striking color plates shows an exquisitely carved and painted wooden deer head found archeo-ogically at Key Marco, Florida. This and other prehistoric examples of southeastern Indian art reveal the high level of achievement attained in that region before the first white men landed on our shores. In other regions Indian art was greatly stimulated by the acquisition of metal tools, glass beads, and other materials of European manufacture. Some of he most appealing pictures in this book are the reproductions of meticulously drawn and brilliantly colored water colors created by modern Indian artists of the Great Plains and southwestern America.

In his concise introduction, Dr. Dockstader points out the considerable antiquity of Indian art in North America, describes the development of regional styles, traces the history of particular arts and crafts, and explains their functions in Indian society. Many examples of Indian art have an immediate appeal to non-Indian viewers, yet he warns against trying to judge Indian art by non-Indian standards. As a member of the Indian Arts and Crafts Board of the United States Department of the Interior, Dr. Dockstader has actively encouraged contemporary Indian artists and craftsmen and aided them in finding markets for their creations. He makes a strong plea for wider understanding and appreciation of this only true native art of North America. This beautiful book is likely to remain for many years the outstanding volume on North American Indian arts and crafts.

Among the many implications to emerge from a consideration of these books, one point is clear: so great was the variety of Indian cultures on this continent that no single tribe can be considered typical of all the Indians in North America or even in the United States. Anyone asking questions about Indians must specify a tribe or area if he expects to receive specific answers.

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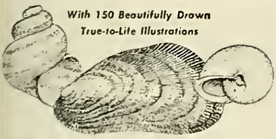

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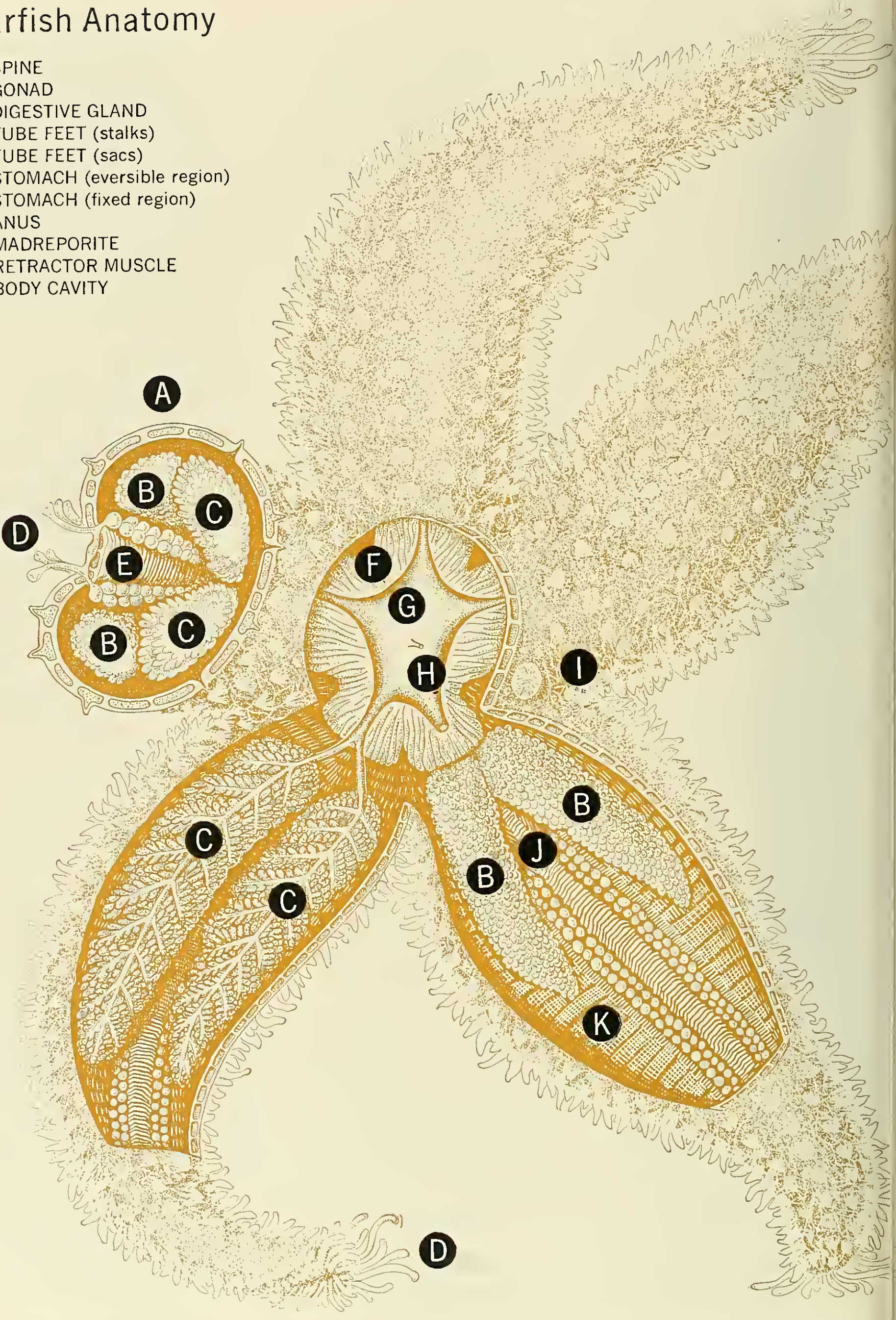
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Enigma of an Echinoderm

Much of the starfish's biology remains a scientific mystery

By Allison L. Burnett

TO THE UNTRAINED EYE the starfish seems to "have little excuse for being alive." The animal possesses no excretory system, no circulatory system, and only the most primitive respiratory system. This would not be too disturbing were it not that most biologists agree that the phylum Chordata, of which man is a member, arose in evolution directly from the phylum Echinodermata (spiny-skinned), which contains the starfish as one of its principal members. Anyone who has seen a starfish slowly gliding over the surface of the ocean floor would certainly be hesitant to claim this creature as a distant cousin.

Thus it is interesting to penetrate beneath the surface of the starfish's spiny exterior and examine the animal closely from the anatomical and physological point of view in an attempt o determine why the starfish is placed in such a distinguished position next to the chordates on the phylogenetic, or evolutionary, tree. Externally the common starfish, *Asterias forbesi*, consists of a central disk from which project five long-pointed arms. On the ventral, or oral, surface of the disk is a mouth-opening that leads almost directly to a large stomach conisting of two chambers. The stomach ills practically all of the area occupied by the central disk. The intestine, which leads from the stomach to a mall opening on the dorsal surface of the central disk, is only a few milimeters in length and is usually unnoticed during cursory dissection of he animal. The anatomy of the arms is identical. Two large paired digestive glands run the length of the arm and are connected by ducts to the stomach. Under the digestive glands are a pair of gonads, connected to the outside medium by pores located at the base of the angles formed where the arms are attached to the central disk. Externally, two rows of locomotory structures, the tube feet, are found along the entire length of the ventral surface of each of the animal's arms.

From this simple anatomical discussion, the starfish appears to be on a relatively low level of organization. However, it possesses one of the most complex nervous systems to be found in the invertebrates; its feeding mechanism is unique in the animal kingdom: its method of locomotion is extremely complex, and is not duplicated outside of the phylum Echinodermata; and finally, the animal's ability to drop an arm when it is disturbed and to regenerate into a complete animal from only a small portion of the central disk is not equaled by any of the higher invertebrates.

Because of the devastation starfish cause in clam and oyster beds, man has sought a long time for methods to control the starfish population. Therefore one would imagine that the starfish has been studied thoroughly by modern scientists from the physiological point of view. Yet less is known regarding the physiology of the starfish than of any other major invertebrate animal. The nature of its digestive enzymes, the mechanism employed by the animal to drop an arm, the physiology of its nervous system, the cellular changes that occur during the regeneration process, the regulation of its locomotory apparatus, and the transportation of food materials within its body are still matters of highest speculation. Furthermore, it is only within the last decade that the mechanisms involved in the animal's feeding process have been elucidated to any considerable extent.

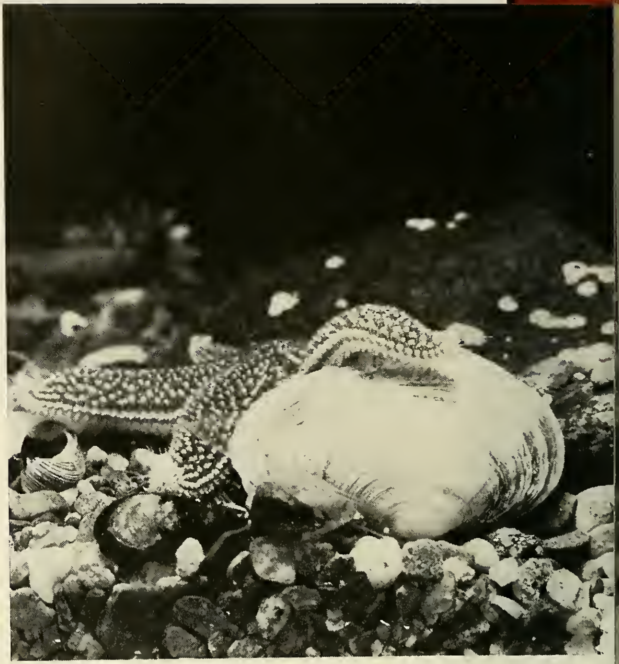
So let us begin by examining what is known concerning the biology of the animal, and end by considering the many interesting problems that are or will be foremost in the experimental program of the modern student of the echinoderms. We will start with a kind of scientific detective story that has been written by investigators during the past 100 years. The problem is: how does a starfish succeed in opening the valves of a clam for the purpose of devouring it? Although the starfish leaves few clues behind except an empty clam shell, it is possible to "catch the starfish in the act," experimentally, so to speak, and here we have been able to find the answer to a most bewildering problem that, unfortunately, still does not solve the very important economic problem of how to prevent the crime.

Since the time of Aristotle naturalists have observed that starfish are capable of attacking, opening, and digesting oysters and clams successfully. Furthermore, one would strongly suspect that many primitive tribesmen who feasted on mussels and oysters long before the time of Aristotle must surely have witnessed the rayed starfish gliding over the valves of the helpless shellfish and feeding on the soft parts of the trapped animal for, under natural conditions, starfish always abound wherever shellfish beds are found in abundance.

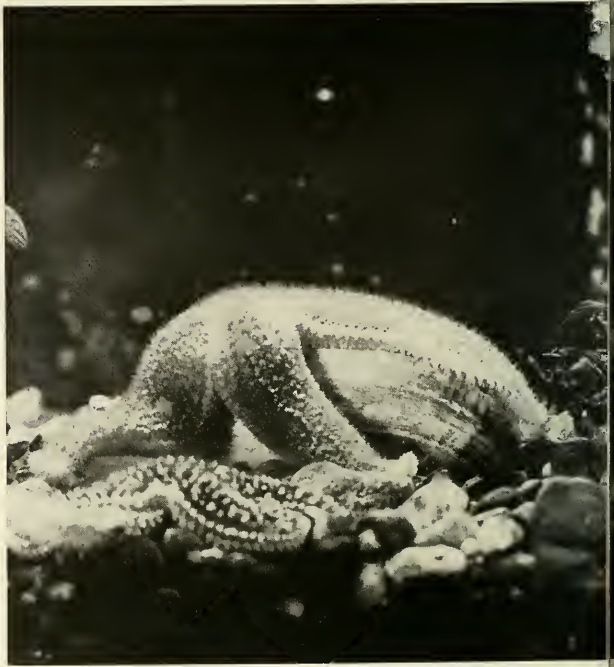
The decimation of shellfish beds was probably no problem for primitive man or even for the early settlers in this country, since enough clams always escaped the ravages of the starfish attack to provide food for local populations. However, as the population of this country grew, the raising and harvesting of clams became an enterprise rather than a means of survival. As early as 1891 it was estimated that the damage done by starfish to oyster beds in Connecticut alone was approximately $463,000, $613,500, and $412,250 for the years 1887, 1888, 1889, respectively. In fact, in 1901 the state of Connecticut passed a law stating, "Every person who shall willfully deposit or assist in depositing starfish . . . in any of the navigable waters of this state . . . shall be fined not more than fifty dollars or imprisoned not more than six months." In spite of the notoriety given the starfish by state judiciary committees, little was known until the last decade regarding the mechanisms controlling the feeding habits of the animal.

First let us observe the basic movements employed by the hungry animal in search of its prey. By means of its dozens of tube feet (to be discussed later), the starfish moves smoothly over the ocean floor. If a clam is in the immediate vicinity with its valves slightly open, the starfish will suddenly veer off in the direction of the clam. When the first arm of the starfish makes contact, the clam immediately closes. The starfish glides over the surface of the clam and assumes a humped position, which it may maintain for several hours. Then it moves away. An examination of the clam reveals that all its soft parts have been devoured, and that nothing remains except the two calcareous valves.

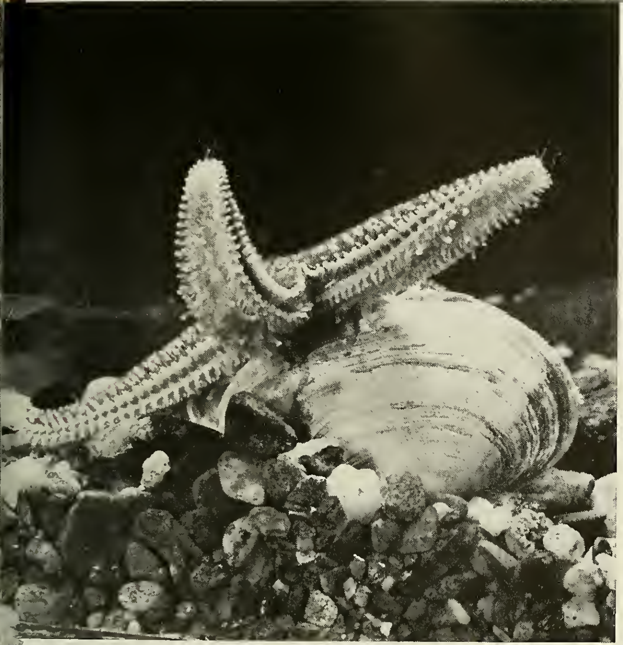
For one hundred years investigators have sought the mechanism by which the starfish gains access to the interior of the valves. The hosts of investigators who have examined this process may be placed in two major schools. The first group hypothesized that the starfish secretes a poison between the valves, killing the clam and causing its muscles to relax and the valves to open. The second group maintained



Starfish assumes a series of typical positions while attacking clam. First, it glides toward its prey, whic first contact of arms, closes its v



Helpless clam is maneuvered back and forth into various positions until the mouth of starfish lies precisely o junction of the tightly closed valv



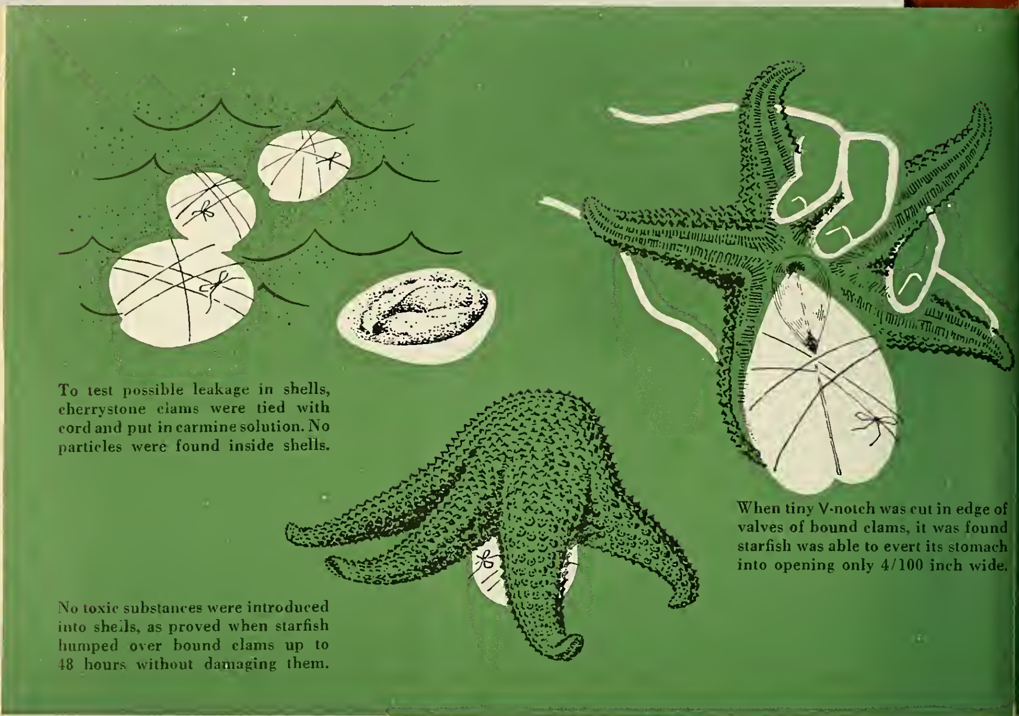
ZENS OF TUBE FEET are visible on erside of the arms as the starfish moves deliberately over the surface of the clam, preparatory to opening shell.

MPED POSITION indicates valves of lam are properly oriented and starfish is about to exert the force needed to pry animal open and begin digesting it.

that the starfish opens the clam by sheer force. More support was given to the "poison" school than to the "force" school until fairly recently.

EXPERIMENTS were undertaken in our laboratory to ascertain which of the foregoing theories could be supported by experimental evidence. First, it was desirable to determine whether the surrounding sea water could penetrate into a clam after it closed its valves. If the starfish did indeed secrete a poison, then the poison would be useless unless it was capable of passing between the clam's valves to the soft parts of the animal. The common *Venus*, or cherrystone, clam was employed in this experiment. Several clams, whose valves were closed, were tied with cord so that it was impossible for the valves to open. These were then placed in a solution in which were suspended microscopic carmine particles. It was assumed that if there were even the smallest opening between the valves, the carmine particles would enter and be found inside the animal after it had been removed from the solution. Upon examination, the clams that had been left in a carmine solution for three days showed no particles in their valves.

This observation implies that poison secreted by a starfish would have no way of entering between the valves of the clam. To further test this hypothesis, another simple experiment was conducted. Eight clams were bound with heavy cord so that their valves could not be opened, and were placed in an aquarium containing a dozen hungry starfish. If a starfish, in attempting to open such a bound clam, injected a toxic substance between the valves, the clam would show some noticeable effect after the starfish had given up in its feeding attempt. All of the clams were attacked by the starfish in the next few days. Some of the starfish were frustrated early by the bound clams and gave up their feeding attempts after eight hours. Others, however, remained humped on the clams for forty-eight hours before crawling away. In all cases, careful examination revealed that none of the bound clams was harmed by the starfish. The clams' hearts were perfectly intact and beating regularly. These experiments further suggested that either no poison was being produced by the starfish, or that if a poison was produced it could not enter the clam's tissues because of



To test possible leakage in shells, cherrystone clams were tied with cord and put in carmine solution. No particles were found inside shells.

When tiny V-notch was cut in edge of valves of bound clams, it was found starfish was able to evert its stomach into opening only 4/100 inch wide.

No toxic substances were introduced into shells, as proved when starfish humped over bound clams up to 48 hours without damaging them.

the protection afforded by the clam's "hermetically sealed" valves.

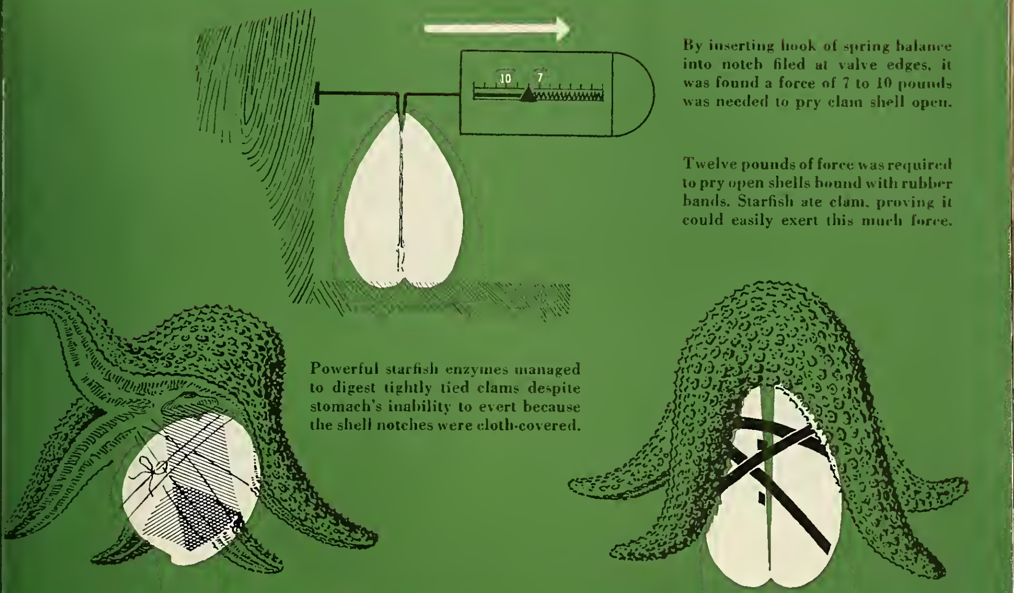
It was decided to attack this problem from another point of view. It appeared possible that the starfish might open the valves slightly through force and then inject a poison between them. In order to test this hypothesis, a small V-shaped notch with an area of approximately 1 to 2 mm.^{2} was filed at the edges of the valves of three clams. The valves were tied shut as before, and the clams were offered to hungry starfish. Upon removal of the clams from the predator, it was noticed that practically the entire stomach of the starfish had passed out of its mouth-opening into the tiny hole in the clam valves. It had been known for a long time that the starfish was capable of everting its stomach during feeding, but the present observation revealed that this large stomach could work its way through an extremely small opening (4/100 of an inch). The clams, furthermore, were almost completely digested.

Bits of the feeding picture now began to fall into place, but a few additional experiments were necessary before anything definite could be said. Small pieces were broken from the valves of several clams, but on this occasion the opening in the valves was covered with a very fine bolting cloth. The clams were then bound in heavy cord, similarly to those in the preceding experiment. However, the intervening bolting cloth prevented the starfish from passing its stomach between the valves. The clams were placed in the water with several starfish. "Clam juice" diffused into the water, and within minutes starfish hanging on the sides of the glass aquarium began to glide down to the bottom and, without hesitation, make their way to the clams.

When the starfish had given up in their feeding attempts and had moved away, the clams were examined. Astonishingly enough, although the soft parts of the clam had never been in contact with the starfish, the clams had been digested! This experiment clearly demonstrated that the starfish possesses an extremely powerful enzyme within its tissues. This enzyme is capable of digesting a clam even after being diluted in sea water and clam juice. Since, however, it is well known that enzymes usually do not digest living tissue, it was still possible that the starfish secreted a combination of a poison and an enzyme simultaneously. Thus, the poison would kill the clam, after which enzymatic digestive action would begin.

In order to test this hypothesis, the foregoing experiment was repeated, but on this occasion, clams were removed from the starfish at different intervals during the feeding process. It was found that after two to five hours several clams had had parts of their external tissues digested, but their hearts were still beating. Thus, it was shown concretely that the enzyme produced by the starfish is literally capable of digesting a clam alive! It was not necessary to postulate that the starfish possesses a poison specifically designed to kill clams.

Only one major problem remained to be answered at this time. Even if the starfish is capable of secreting an enzyme that will digest a living clam, how does the enzyme reach tissues that are hermetically sealed? Since it had been shown that the starfish could pass its stomach through an incredibly small opening, it appeared possible that if the starfish were capable of pulling open valves of a clam a mere 4/100 of an inch, then it would be able to evert its stomach, pass its stomach between the



By inserting hook of spring balance into notch filed at valve edges, it was found a force of 7 to 10 pounds was needed to pry clam shell open.

Twelve pounds of force was required to pry open shells bound with rubber bands. Starfish ate clam, proving it could easily exert this much force.

Powerful starfish enzymes managed to digest tightly tied clams despite stomach's inability to evert because the shell notches were cloth-covered.

valves. and begin enzyme secretion.

Anyone who has ever attempted to open a good-sized *Venus* clam by simply pulling the valves apart realizes that it takes a tremendous force to accomplish this feat. Earlier investigators had argued that the starfish need not apply such a force to the clam at all. They claimed that if the starfish applied a steady small force, the clam's muscles would eventually tire and the valves would open.

An experiment was undertaken to determine. first. if the starfish could open the valves through sheer force. and second. if this was accomplished through a small force acting for a long period of time. A small notch was filed in the middle of the edge of the clam's valves. The hook of a spring balance (the type used by fishermen) was then inserted into the notch. and the force required to open the valves 1 or 2 mm. was recorded. After testing several clams it was learned that a force of 7 to 10 pounds was necessary in order to produce even this minute opening between the valves.

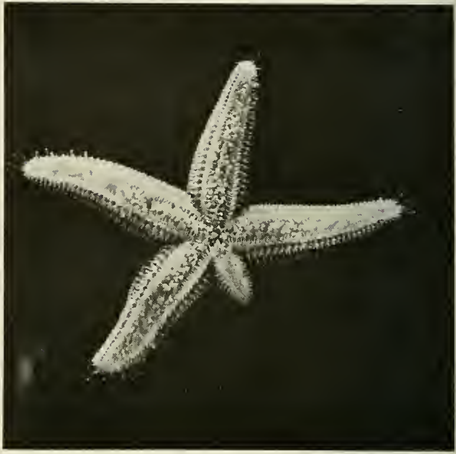
These clams were then forced open and the muscles that normally hold the valves together were severed. The clams were then wrapped up with strong rubber bands until a force of 12 pounds was required to pull them open with a spring balance. It was reasoned that if a starfish could open a clam with a resistance of 12 pounds. it could also open normal clams whose average resistance to opening is only 7 to 10 pounds. Furthermore, the rubber bands. unlike normal muscle, would not be subject to fatigue.

SEVERAL clams whose adductor muscles had been severed were then wrapped in rubber bands and dropped into a tank containing several starfish, which invariably attacked them. Often a portion of the valves protruded between the arms of the starfish, making it possible for an investigator to determine whether or not the valves were being forced apart. After the starfish had assumed their humped feeding position. it was noticed that a definite gap of about 2 mm. appeared in the valves of the bound clams. After a few minutes the valves snapped shut again. presumably upon the everted stomach of the starfish. This alternate opening and closing of the valves often continued for approximately a half hour. By that time the starfish had oriented itself perfectly and was able to hold the valves open for as long as 10 minutes at a time with ease.

Thus. the starfish-clam mystery is largely solved, but many questions still remain to be answered. First, if the starfish everts its stomach. how is it able to ingest food materials from the digested clam. and second. how is it able to evert and withdraw its stomach? Anderson (1954) has studied this problem in some detail. He has shown that the stomach of the starfish is lined with cells that bear a tiny whiplike thread or flagellum on their surfaces. These flagella, by whipping strongly back and forth. produce a current of water that passes back into the part of the stomach that has not been everted on feeding. This water current carries with it many digested food particles from the clam's tissues. The particles either are absorbed by the cells in the stomach or pass into tubes that lead to the large digestive glands lying in each arm. Here the food materials are absorbed by special digestive glands. There is also good evidence that cells in the digestive glands secrete the powerful enzymes that digest clam tissues.

The eversion process itself is more of a mystery. Anderson believes that during the eversion process the longitudinal musculature around the mouth-opening contracts, forcing the

Ventral surface of a normal starfish exhibits the rows of tube feet and the five radiating arms of equal length.



This starfish has lost an arm and is regenerating a new one, which will attain size of the others after a few weeks.

mouth open. At the same time there is a contraction of the muscles of the arms. This contraction, which narrows the diameter of the arm, forces body fluids inside the arm against the walls of the stomach. This force causes the stomach to pass out the mouth-opening.

The fact that increased pressure inside the body cavity of the starfish causes the stomach to evert through the mouth can easily be demonstrated. If 5 cc. of sea water are injected into each of the starfish's arms to increase the internal pressure in the animal's body cavity, the stomach will evert through the mouth-opening. Connected with the stomach are small paired muscles that run from the stomach into each arm, where they are anchored. It is supposed that upon retraction of the stomach the muscles in the arm relax, releasing the pressure of the body fluids upon the everted stomach. At the same time both the small retractor muscles attached to the stomach and the muscles in the wall of the stomach contract. This serves to pull the stomach back through the mouth-opening. Such a feeding method has no counterparts in the animal kingdom.

Earlier it was said that very little is known concerning the physiology of the starfish. The reason is that until a few years ago, no one had been able to operate on the animal with any success. If one is interested in knowing the function of the digestive glands in each arm, for instance, the natural experimental approach would be to extirpate or to ligature the ducts leading to this gland and to see how the biology of the animal is affected. However, if a cut is made in the starfish's arm to reveal the digestive gland, the investigator finds that while he is working on the arm, the rest of the starfish, consisting of the central disk and four arms, has moved away. This process of dropping off a part that has received a noxious stimulus is called autotomy. In other groups of animals, such as the arthropods, many species have a weakened area in each limb. This breaks when the animal tries to escape from an attacker who has seized a limb. No such weakened area appears in the starfish in spite of the fact that the arm breaks at the same point whenever the animal is disturbed. If one forcibly tears off a starfish's arm it will not break at the point where it does when an incision is made in the arm during an operation. The starfish itself is the sole determiner of when and where the arm will be broken. The author has found that if a strong electric current is applied to the central disk of the animal, all five arms will walk away from the body, leaving the central disk alone under the electrodes. Examination of this process reveals that during autotomy the tissues at the base of the arm become soft and partially liquified. All the muscles' connective tissues in this area are involved in this "softening" process. The mechanism of the autotomy process, the changes that occur in the degenerating connective tissue and muscle, and the exact nature of the stimulus required to cause autotomy are questions that are still unanswered. Preliminary evidence suggests that the nervous system is involved in the process. Anderson found that if the starfish is immersed in an anesthetic (such as magnesium chloride in sea water) it will not autotomize its arm during an operation. This was a very important step in the scientific history of the starfish, as it is now possible to operate on the animal. After the operation, the starfish may be placed in normal sea water. It recovers admirably from the anesthetic, and does not appear disturbed.

Dr. Burnett, whose study of hydras appeared in this magazine in 1959, is Associate Professor of Biology at Western Reserve University in Ohio.

One might wonder what happens to the starfish that drops its arm in the autotomy process. The answer to this question was learned by fishermen who removed starfish from clam beds, hacked them to pieces, and threw them back into the water. Each of the excised pieces promptly started to regenerate, and the hapless fishermen finally realized that by chopping up the starfish they were only increasing their numbers. It has been shown that an arm plus only a very tiny portion of the central disk will completely regenerate into a normal animal. The processes occurring in the tissues during regeneration are only now being studied in any great detail.

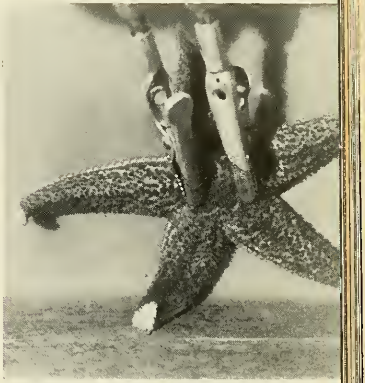
Another major system, which has not been discussed, is that controlling locomotion. The starfish possesses one of the most remarkable systems of locomotion in the entire animal kingdom. On the dorsal surface of the central disk is a small, porous, calcified plate called the "madreporite plate." Currents in a canal leading from the madreporite into the interior of the animal cause a flow of water to enter from the outside. These currents, like those in the stomach, are produced by hairlike structures lining the inner canal. The water is ferried through a series of canals until it reaches the arm. Here small off-shoots from the main canal system lead into each of the many tube feet that can be seen lying in two rows along the animal's ventral surface. The tube feet have a unique structure: inside the animal the tube foot is represented by a sac filled with water; outside is a stalk connected directly to the sac. At the end of each stalk is a suction cup. When the starfish moves, each of the sacs contracts, forcing water into the stalk portion of the foot. This causes the stalk to lengthen greatly. When the suction cup comes into contact with a surface, the tube foot becomes attached. After attachment, the longitudinal muscles of the stalk contract. This contraction serves to force the water back into the sac and to draw the starfish forward. The process can easily be visualized if one imagines throwing an anchor line from a boat to the shore. If the anchor line contracts, the boat moves shoreward. The starfish moves by constantly throwing out hundreds of these anchors. It will be recalled that during feeding the starfish glides over the clam and pulls it open. The attachment of the starfish to the clam is accomplished by the dozens of suction cups that the starfish has applied to the clam valves. Their combined force must restrain a force of at least twelve pounds, as was shown in the earlier experiments.

When one considers that the starfish has five arms, all radiating away from the central disk, it is apparent that when the starfish moves forward only one arm is in the lead. The two arms that are behind the lead arm are pointed to the sides of the animal, and those in the rear are also, in a sense, pointing to the side. Therefore, when the starfish moves, the tube feet in the front arm must be extended directly forward, while those in the remaining arms must be projected to the side. If the starfish changes its direction another arm takes the lead and all the hundreds of tube feet must switch their direction in a perfectly harmonious manner. Obviously, the nervous system of the starfish must be exceedingly complex in order to regulate the walking movements of this multiplicity of feet. Smith (1947) has stated that the nervous system of a single starfish, with all its various nerve ganglia and fibers, is more complex than London's telephone exchange.

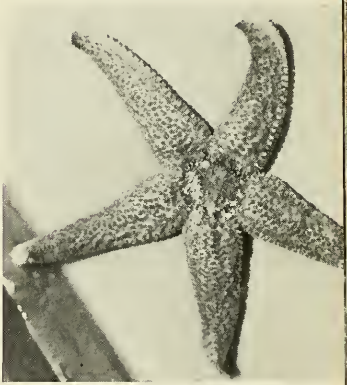
It was stated at the beginning of this paper that biologists are in general agreement that the chordates arose in evolution from the echinoderms. Evidence is based on the facts that early chordate larval forms are similar to those of echinoderms; echinoderms and chordates form their body cavities in approximately the same manner; both groups have an internal skeleton; and an energy storage compound found in vertebrates is also found in the echinoderms and nowhere else in the invertebrates.

We have found preliminary evidence indicating that still another major similarity may exist between echinoderms and chordates—the nervous systems of the two groups. It is a well-known fact that in the vertebrates two major types of nervous stimulation of muscles can be demonstrated. One group of nerves liberates adrenalin at the nerve ending and the other group liberates a substance called acetylcholine. These two systems are said to be reciprocal to one another, that is, if the liberation of adrenalin causes one type of muscle to contract, then the liberation of acetylcholine on the same muscle will cause it to relax, and vice versa. Through this reciprocal action our voluntary and involuntary movements are maintained. If our heartbeat is very slow, the addition of adrenalin will cause it to speed up. Further addition of acetylcholine will cause the beat to slacken.

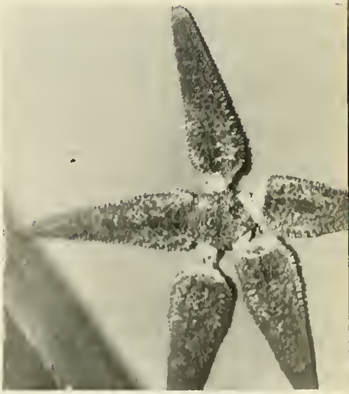
Although some invertebrates have been shown to possess sensitivity to adrenalin, there appears to be no clear-cut example of an invertebrate that has adrenergic and cholinergic systems that can function reciprocally.



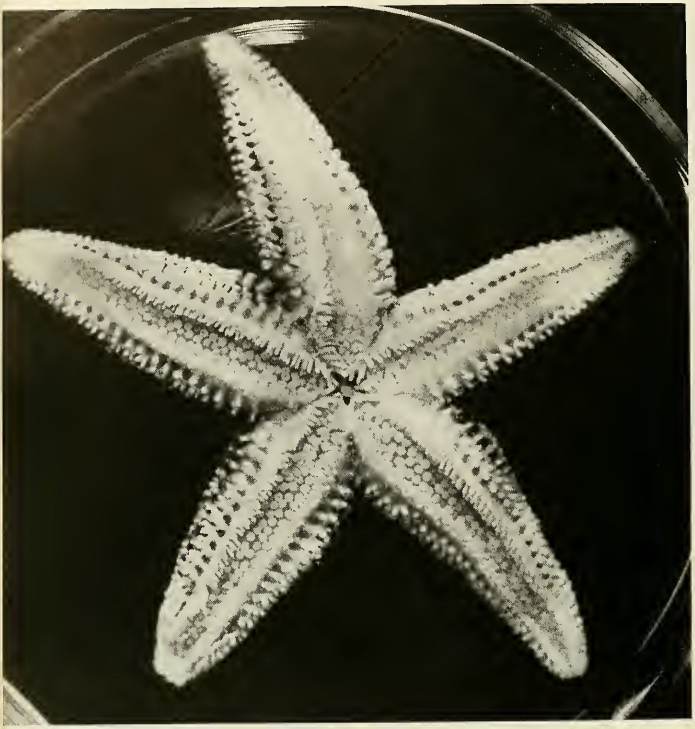
Autotomy occurs when electrodes are placed on disk surface and shock given.



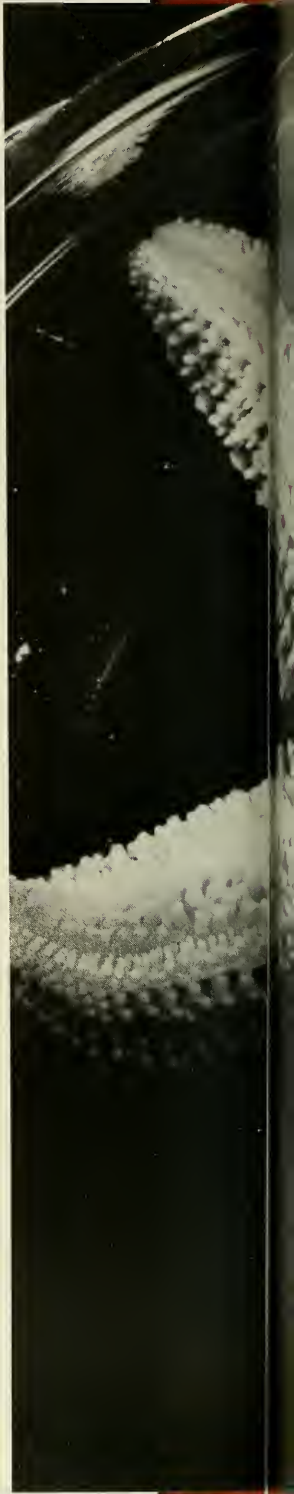
After shock, break occurs in muscles under the skin close to the central disk.



Break shows in skin as well, as the arms "walk away" from central disk.



Tiny mouth of starfish is visible in the middle of the central disk, *above.*



Stomach, ***right,*** **has been forced out past mouth by muscular contraction.**

We have conducted several experiments to elucidate the mechanism of nerve action in the starfish. First, it was found that adrenalin itself is not effective. The closely related substance nor-adrenalin, which is found in the lower vertebrates, does have an effect when applied to the tissues of the starfish. In our studies we have tested the effects of nor-adrenalin and acetylcholine on muscles in the tube feet, mouth, stomach, body wall, spine musculature, and several other body structures. In every instance it was found that if acetylcholine caused contraction of a muscle, adrenalin brought about its relaxation faster than normal sea water. Furthermore, it was found that when nor-adrenalin is added to the apical muscles, which run the length of the arm, the muscles contract and the arm is lifted. Also, if adrenalin is added to the digestive glands, they lengthen. Such a lengthening could be caused by small contractile fibers that connect the glands to the body wall. When acetylcholine is added to these structures, the lifted arm relaxes and the digestive glands are shortened. Thus, there seems to be evidence that the starfish possesses a nervous system containing basic elements found in the nervous system of the vertebrates. If it is indeed true that no other invertebrate animal possesses such a reciprocal system, it is additional evidence for the evolution of chordates from echinoderms.

It should be realized by this time that the starfish, which occurs by the thousands along our Atlantic and Pacific coasts, is still largely a scientific enigma. Any of its systems that the modern investigator chooses to examine is open for study and will offer years of research material. It seems only proper to close with a quotation from Dr. Libbie Hyman's great treatise on the echinoderms, which was published in 1955: "I also here salute the echinoderms as a noble group especially designed to puzzle the zoologist."

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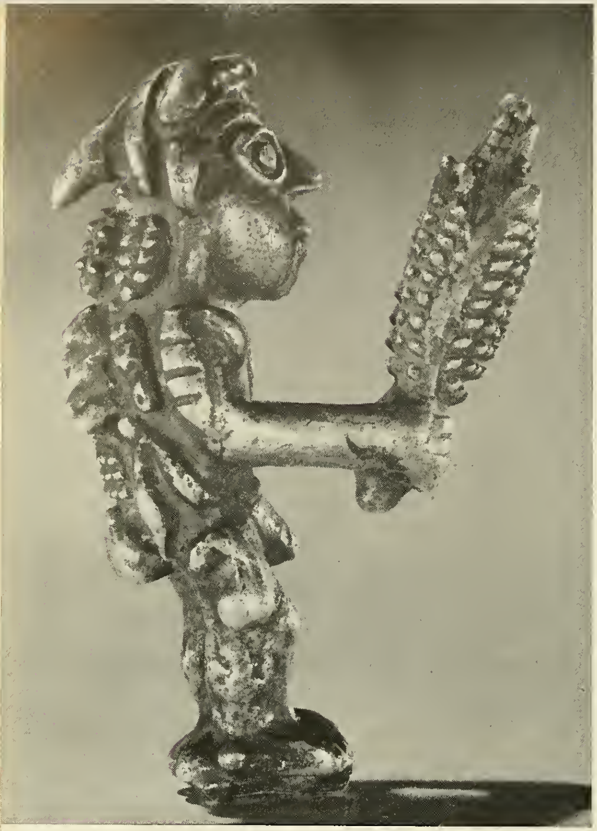
Expressive Art of Old Peru

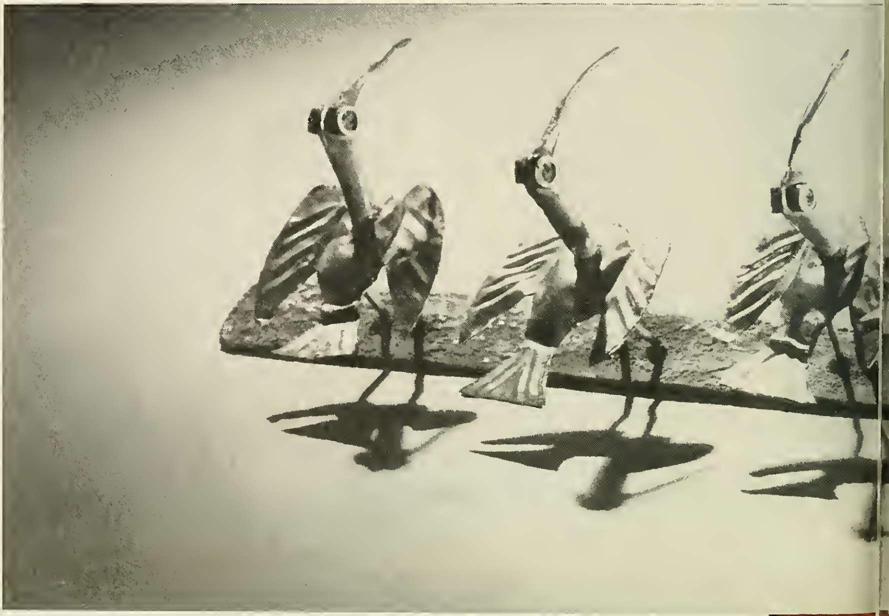
METAL, stone, and pottery speak silently today of pre-Incaic Peru, whose peoples left no written records. But in their material possessions, such as utensils, ornaments, and textiles, the inhabitants of ancient Peru created durable messengers to bring their story to future scholars and art lovers. The perceptive photographs of Peruvian artifacts on these pages were made by Lee Boltin. These objects and other examples of art forms from the prehistory of Peru figure in the exhibition of "Art and Life in Old Peru" that opened this past September at The American Museum.

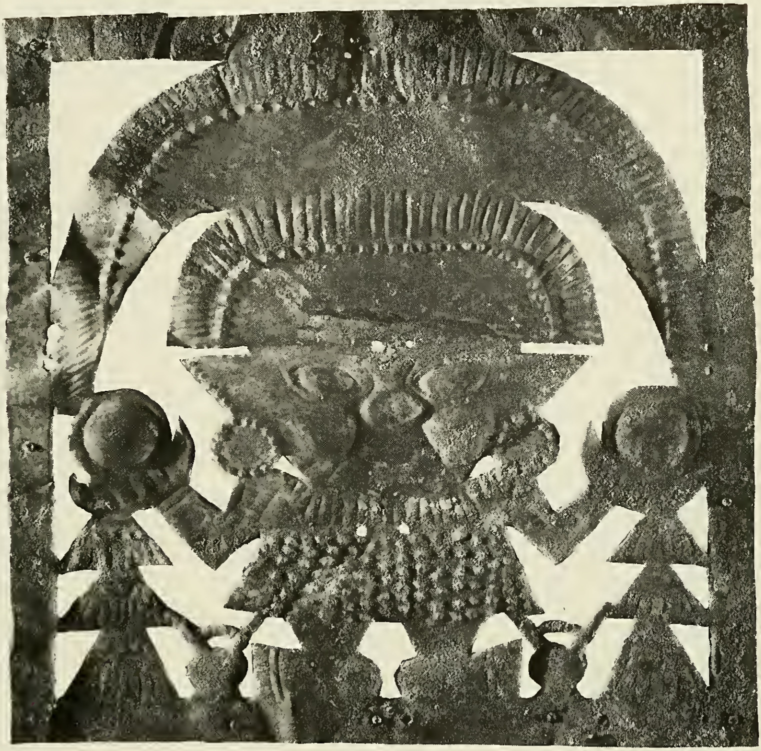


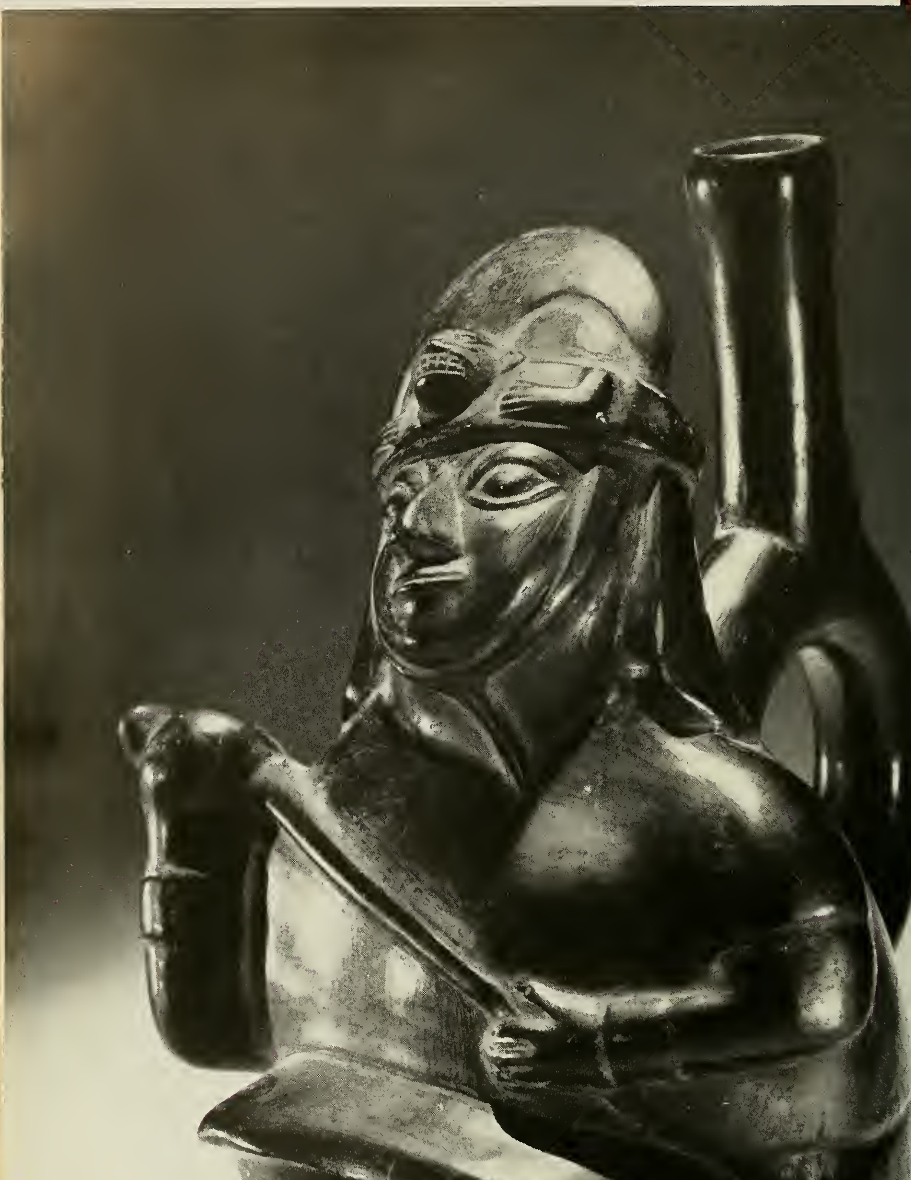
Cast silver figure, just over three inches tall, may be dancer dressed for harvest festival. Man holds cluster of five ears of corn.

Hammered copper plaque, more than a foot square, is from Chimu period. It represents a chief, a ruler, or perhaps a deity.

Six birds of sheet gold stand on a base made from a silver bar nearly nine inches long. Base served as mounting for this ornament.

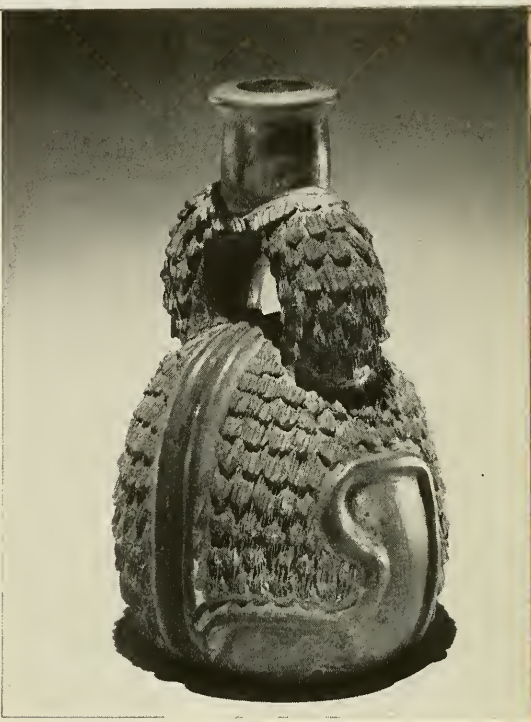




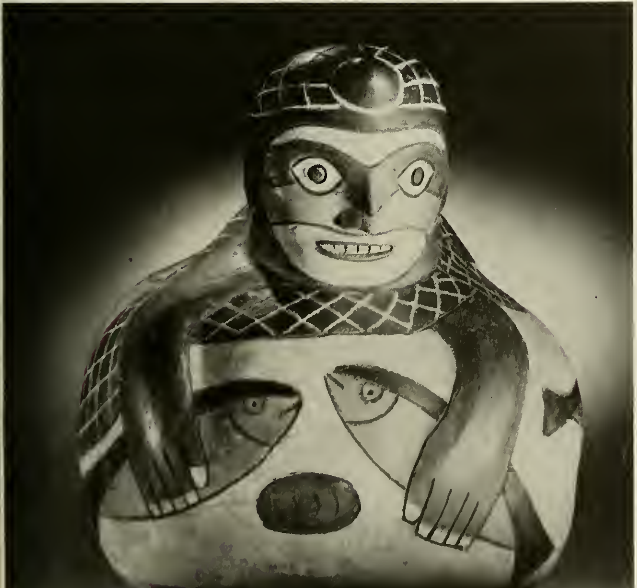


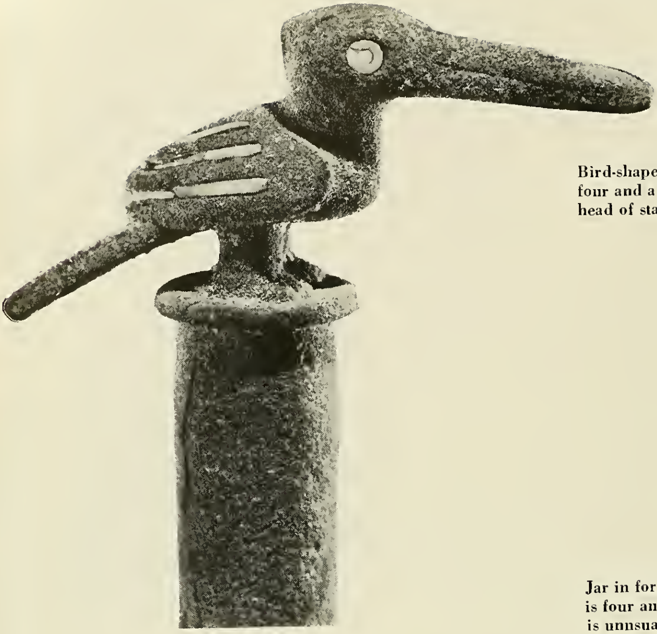
Chimu period blackware water jar, almost nine inches tall, dates from century before conquest. The artist has copied a much older jar showing a Mochica warrior.

Water jar perhaps from eighth or ninth century B.C., nearly ten inches high, illustrates the skill of Cupisnique potters in creating areas of contrasting texture.



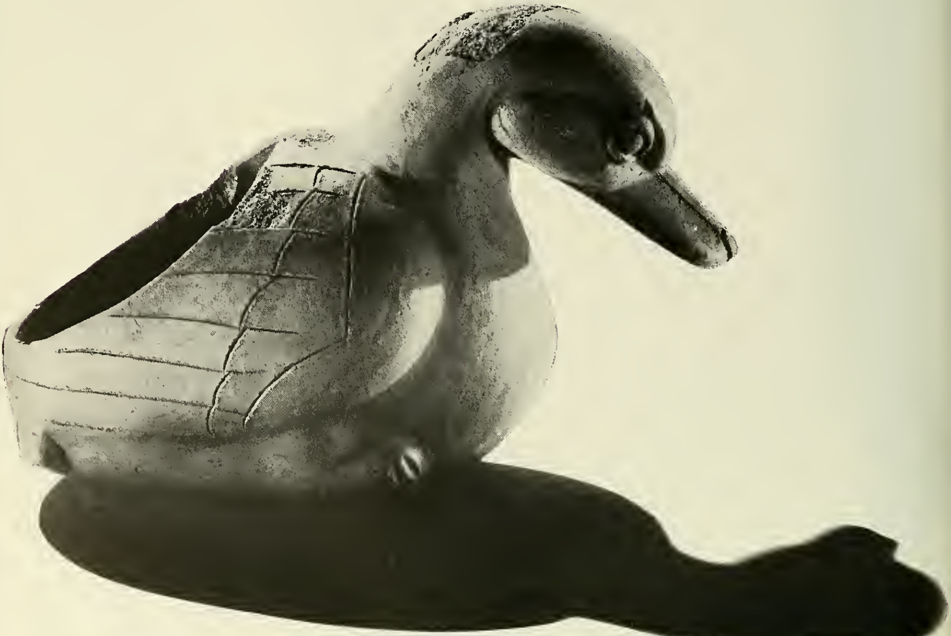
Water jar of early Nazca culture shows a swimming fisherman. Over eight inches tall, the jar shows traditional incised outlines plus newer, fired ceramic pigments.

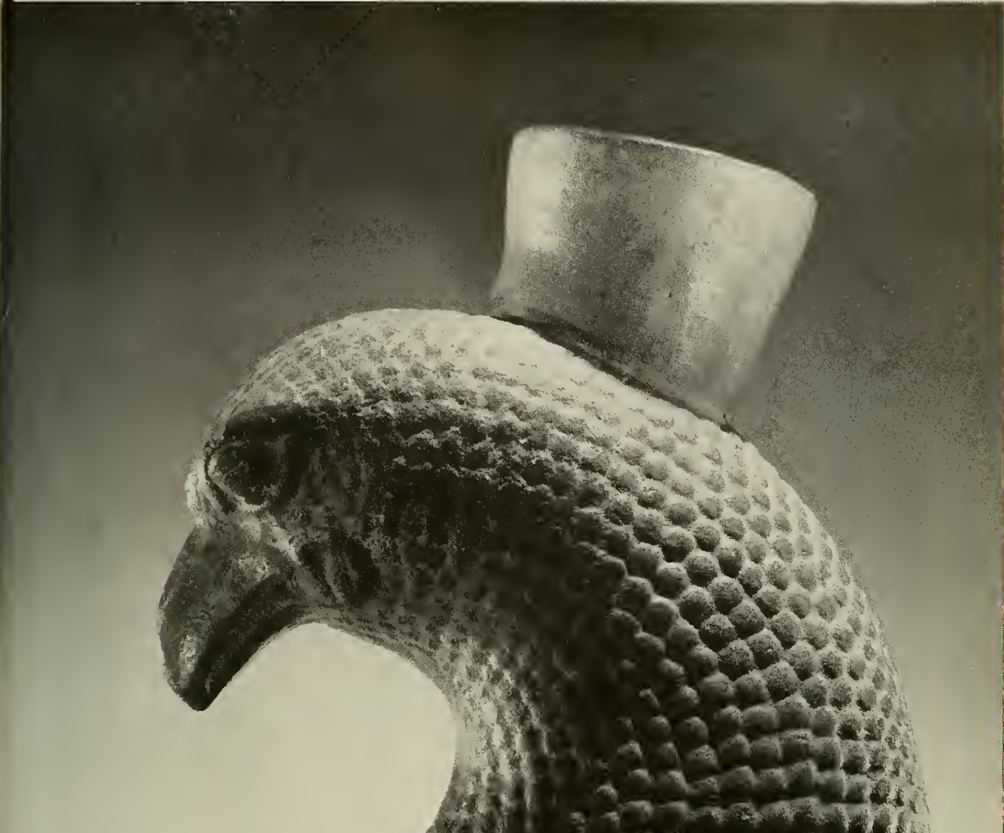




Bird-shaped finial of cast copper, about four and a half inches tall, may have been for head of staff. Wings, eyes, are shell inlays.

Jar in form of duck, *ca.* A.D. 500 to 700, is four and a half inches high. Incised design is unusual in pottery of this period.





Water jar, nearly a foot high, resembles squash with a hawk's head in place of stem. It may have been made between A.D. 600 and 800.

A Continental Water Bird

The American white pelican nests inland

By Robert Cushman Murphy

That the pelicans are basically inland birds may come as something of a surprise, especially to Americans familiar with the southerly coasts of the United States, where pelicans are likely to be regarded as "sea fowl." That would be true, in a sense, of the brown pelican, which breeds along tropical and warm-temperate seashores of the New World; it has even crossed 600 miles of open ocean to establish itself at the Galápagos Archipelago. This leap, however, represents a unique maritime adventure in the history of the pelican family. All the eight species are strongly land-bound birds and most inhabit continental interiors during the nesting season.

The white pelican is a member of the inland group, even though much of its population reaches southern seacoasts in the non-breeding period. The species nests in western North America from Texas and the Great Salt Lake to British Columbia, Saskatchewan, and Manitoba, and eastward as far as the Dakotas. A few wander as far north as Great Slave Lake in Canada's Northwest Territories and there are scattering records from nearly all the eastern states. The winter range extends southward through Mexico to Guatemala.

John James Audubon, who wrote a delightful and scientifically sound biography of the brown pelican, became casually acquainted with the much larger white species when he moved from eastern Pennsylvania to Henderson, Kentucky, on the banks of the Ohio River. He rightly regarded the huge bird as a visitor from the "Fur Countries," and added that he could give no account of its nest, egg, or young because he had never visited the territory in which it breeds. Nevertheless, in 1838 he christened it *Pelecanus americanus* with a characteristic Audubonian flourish: "I feel great pleasure, good Reader, in assuring you, that our White Pelican, which has hitherto been considered the same as that found in Europe, is quite different. In consequence of this discovery, I have honoured it with the name of my beloved country, over the mighty streams of which, may this splendid bird wander free and unmolested to the most distant times, as it has already done from . . . unknown antiquity."

Audubon, despite his peerless gifts, was ignorant of the fact that J. F. Gmelin, a follower of Linnaeus, had 49 years earlier bestowed upon the American white pelican the name *Pelecanus erythrorhynchos*, by which it is still known to ornithologists. The long specific name means "red-billed." Actually, the color of the beak and the naked skin around the eye is orange rather than red. Neither Audubon nor Gmelin had an inkling of the hypothesis that the American and Mediterranean white pelicans represent two branches of the same original, more widely distributed, preglacial stock. Divided and restricted by the Ice Age, each of these birds has since followed its own evolutionary course.

At the beginning of the breeding season the American white pelican grows a curious keel-shaped, horny ornament on the top of its beak. To be safe from predators the birds nest mostly on islands within lakes. The large colony here depicted is at such a site—the Anaho Island Wildlife Refuge, on Pyramid Lake, in northern Nevada. This is the largest nesting ground of the white pelicans in North America: it is estimated that 11,000 birds raise their young here. Sometimes the birds nest *in* a lake instead of on shore, as was true in Oregon before beautiful Klamath Lake was drained, quite unsuccessfully, for agricultural ends. In the Klamath water large floating mats of dead cattails and

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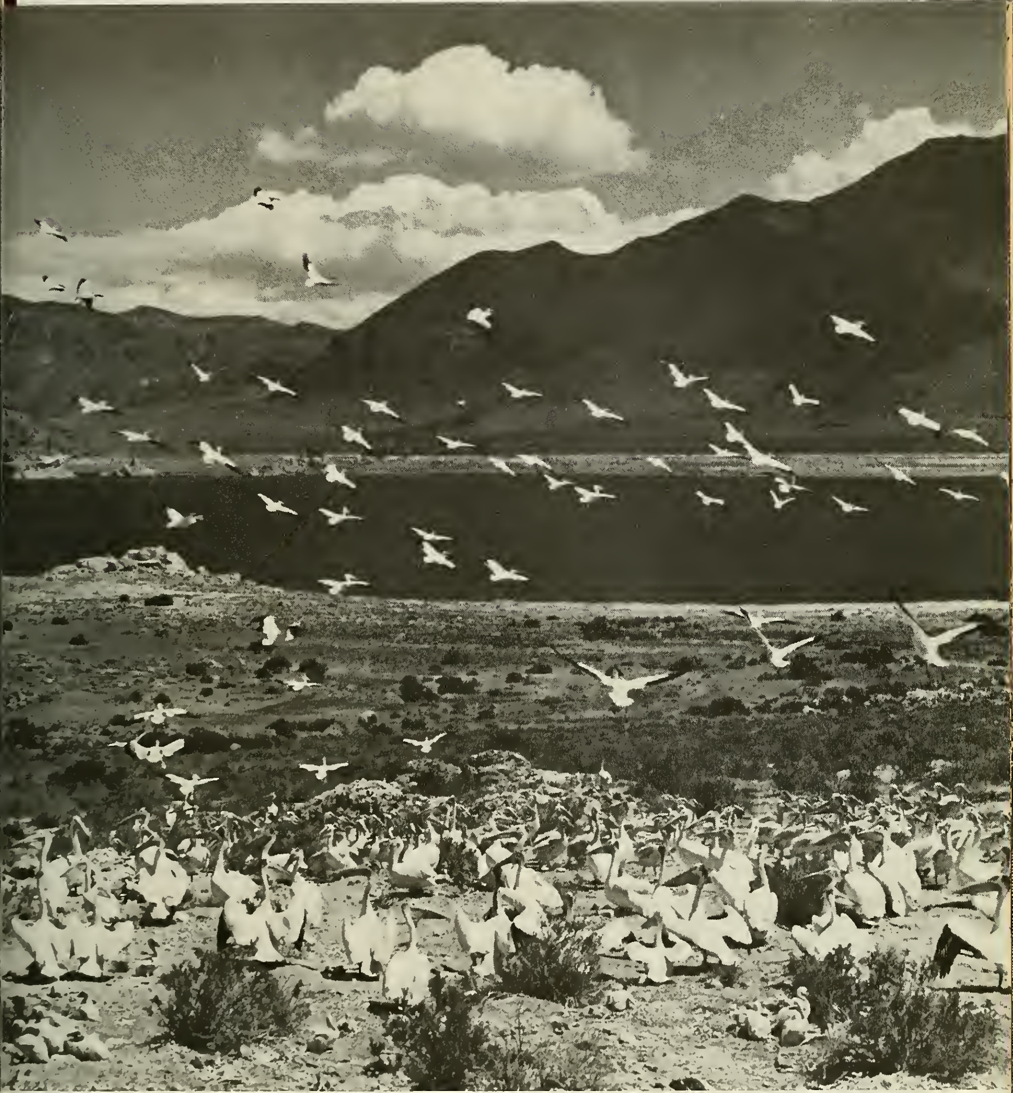
Lamont Curator Emeritus of Birds at The American Museum of Natural History. Dr. Murphy is a frequent contributor to the magazine's pages.

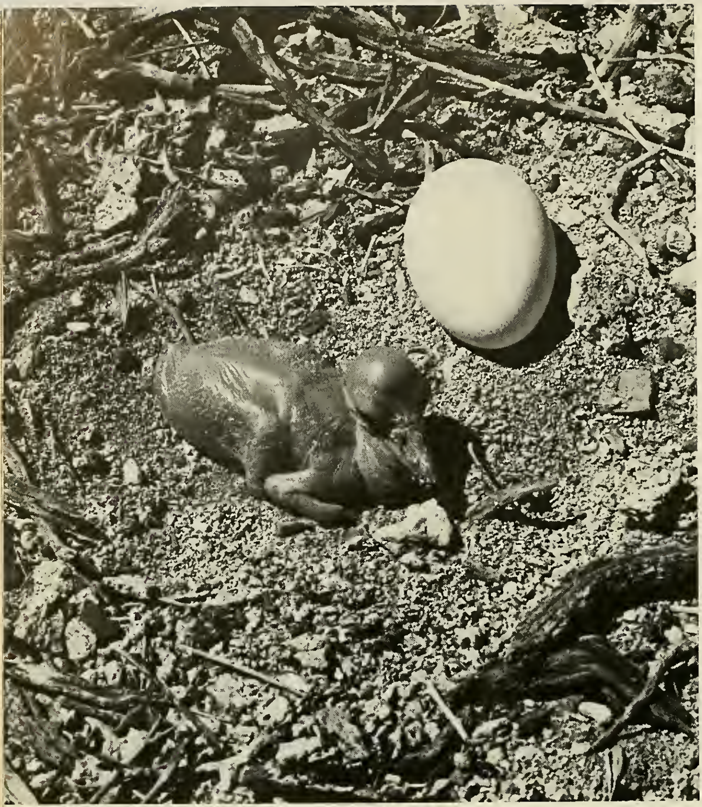


Flock of pelicans, *above,* is a part of the colony that nests at Anaho Island. Pyramid Lake, Nevada—largest North American breeding ground for species.

rushes formed islets, through which green shoots grew up each spring. On such unstable platforms white pelicans laid their eggs and reared their families among cormorants, ducks, gulls, terns, and yelping avocets, the customary pelican neighbors.

The white pelican is one of our largest birds, weighing up to 20 pounds and having a maximum wingspread of close to ten feet. Its nesting habits are generally similar to those of the brown pelican except that it never builds in trees or swamp shrubs as does the latter. Two or three eggs are laid a year; they are covered with a thick, chalky deposit. The eggs are incubated for about 29 days, and then hatch as featherless, black, rubbery, and helpless chicks. They grow rapidly, though, and acquire a white down. By the time they are half-grown, they begin to toddle from the nest, and even to swim.

It is the feeding habits of the pelicans, of course, that gave rise to their reputation for remarkable voracity. Young pelicans are fed by regurgitation: that is, they push their bills down into their parents' pouches for predigested food. A popular fallacy is that the pelican *stores* food in its pouch: actually it swallows the fish soon after catching it. A less known fact about the behavior of pelicans is that the young, abandoned by their parents before they have learned to fly

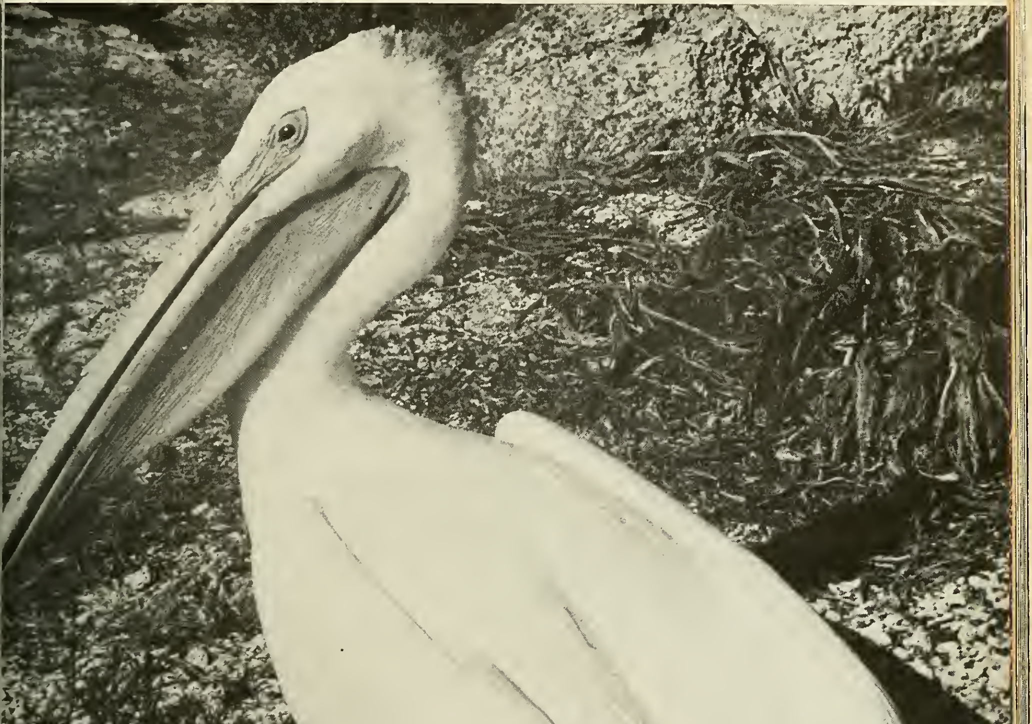


White pelican chick, with its black, rubbery skin, *above*, is newly hatched from one of the two eggs laid in this nest. Helpless now, bird will soon be able to toddle and swim, but mortality rate among pelican young is very high.

and forage for themselves. must live for a while on their own fat.

The white pelican's technique of fishing departs widely from that of the brown pelican. White pelicans never dive from the air; they wade or swim, usually in company, and scoop up prey by thrusting the head and beak beneath the surface. An adult can consume one-third of its own weight in the course of a single foray. Captive white pelicans quickly learn to catch fish tossed toward them, showing as much agility as toucans in a zoo snapping cherries out of the air.

White pelicans are scarcely graceful on the ground, but in flight neither swallow nor falcon can outdo them. The following description is from the pen of the Oregon naturalist, William L. Finley: "After returning from the fishing grounds and lounging about the nests for a while the pelicans began to circle over the colony in a large company, rising higher and higher till they were almost lost . . . flashes of white as the snowy breasts reflected a gleam of the sun. For hours the sky would glitter with these great birds as they soared about. Then it was thrilling to see some of them descend with ...half-closed wings. They used the sky as a ... toboggan slide and dropped like meteors, leaving a trail of thunder."



Adult pelican, *above*, could be approached only because it was too old to fly. Note characteristic webbed feet and the stretchable, almost translucent membrane that forms pouch.

Nervous and easily upset, a pod of immature pelicans will nestle together, *left*, when disturbed. They leave nests and waddle about, aiding weak legs by using wings as crutches.

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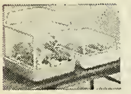

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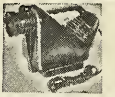

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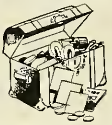

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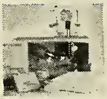

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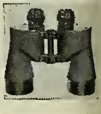

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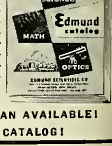

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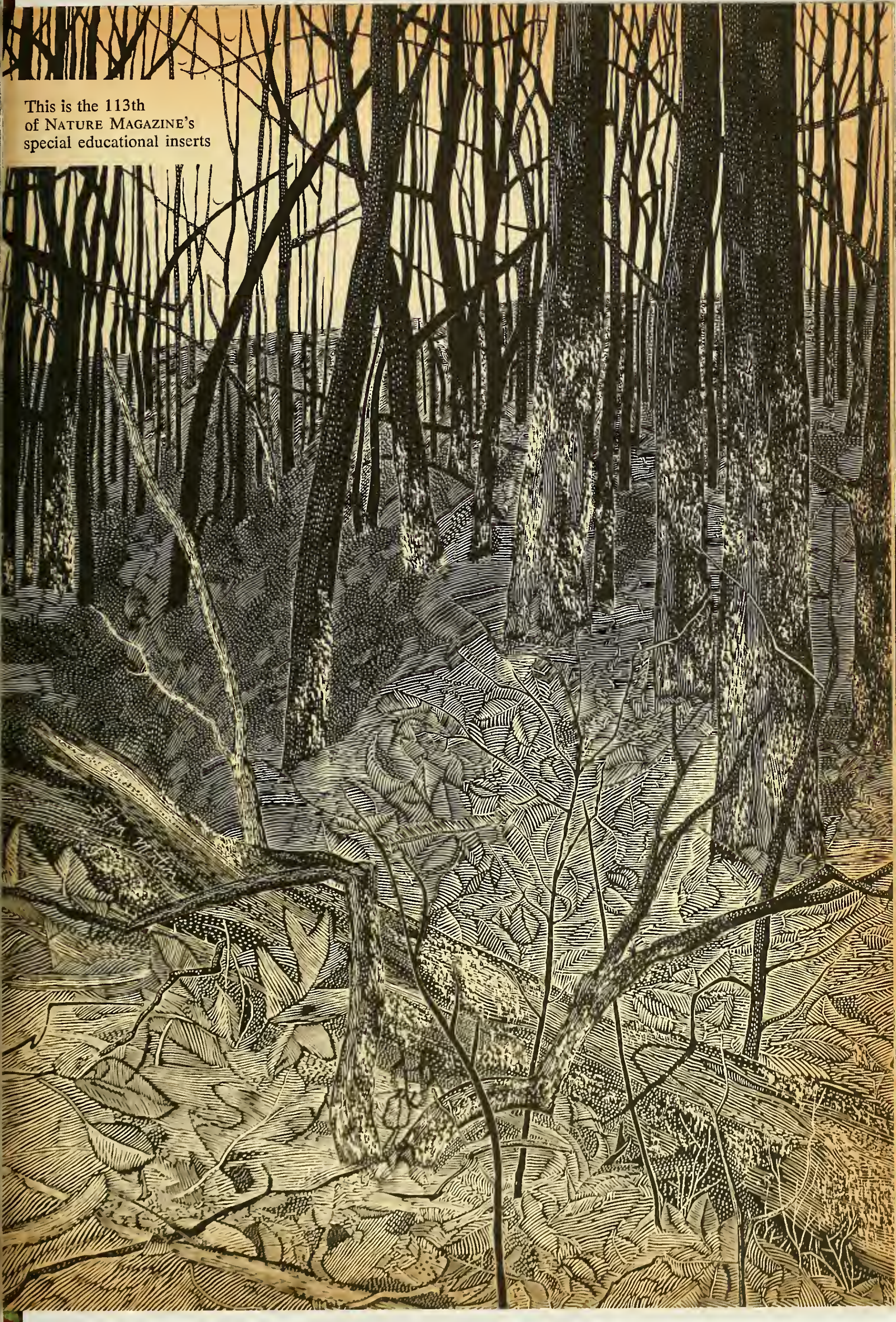


THE LICHEN PARTNERS

Unusual relationship between algae and fungi aids soil growth

By E. Laurence Palmer

One of the most familiar words in public print these days is "coexistence," a term used to describe that rather vague state of human relationships in which neither of two factions makes a hostile move for fear the other might prove stronger. The term, however, is not exclusively applicable to the social life of *Homo sapiens*; in quite another sense, there are also many coexisters in the lesser ranks of the natural world. Among such are the lichens, which may possibly have been among the first forms of life to appear on earth. The lichens represent a successful plant interrelationship that might well be called a coexistence; and while, for the most part, they do not compete with other plants in their usefulness to mankind, they nevertheless deserve a better understanding on our part.

A lichen is never a single plant. It is invariably a close association of two widely differing and primitive plants, the algae and the fungi. Authorities disagree as to the nature of this relationship; but, whatever its true nature, it is at least workable within certain limitations. It is recognized that the algae concerned are green or blue-green, and are capable of manufacturing carbohydrates in the presence of sunlight, air, and water. It is also recognized that these algae can, and do, exist independent of the fungi, with few, if any, modifications. However, while the algae can exist alone, they are not so prosperous as when combined in a lichen, where they are held in place and anchored against removal by wind, water, or other disturbances. The algae function most effectively under optimum conditions of light, water, air, and temperature, where suitable minerals are available; but they can suspend operations without serious loss.

Some of the algae involved in the lichens were discussed in the sixty-ninth unit of this educational series, others are dealt with in textbooks on botany. No one family or genus of algae is involved in the lives of the lichens, and different species of lichens of one genus may entertain different species or different genera of algae as partners. The genera of algae most commonly involved are probably *Protococcus, Pleurococcus, Nostoc, Gloeocapsa, Scytonema, Calothrix, Chroococcus, Xanthocapsa,* and *Trentepohlia*. Interestingly enough, when these algae become involved in the lichen complex, they lose some of the characteristics exhibited when they are independent. They regain these if they are later freed.

There is at least one exception to the general rule that the fungi involved in the lichen complex are sac fungi, or Ascomycetes (a group that includes the yeasts, mildews, and the fungi that produce the antibiotic penicillin). Since the fungal part of a lichen association is more obvious to the human eye than the algal, the lichens are named after the fungus rather than the alga. In G.G. Nearing's *The Lichen Book*, published in 1947, more than a thousand species of lichens are recognized, and most of them are figured and described; yet, even then, Nearing's book does not attempt to describe *all* the known kinds of lichens.

The role of the algae in the lichen partnership is that of producing food for themselves and their partners, the fungi. If the algae have access to the necessary light and water, and the temperature is suitable, they produce food in any case; so, as we have said, they are relatively independent. But this is not the case with the fungus associate. The fungi in a lichen partnership cannot live independent of the algae for long; and although they may be the more conspicuous both in appearance and volume, the fungi are probably the more dependent upon the association type of existence.

The fungus partner is able to obtain and hold water—and water is a part of the lifeblood of every living thing. The fungus can also hold an established position; it is not easily washed away by water or blown by wind. This means that, once established, the fungus is not likely to be buried where sunlight and fresh air cannot each it—a factor of great importance to the growing ociety of alga and fungus that constitutes a lichen. 'ungi commonly are destructive agents, but in the lihens they do not destroy the algal part of the "corporaion." Instead, they obtain their nourishment from the lgae without destroying them.

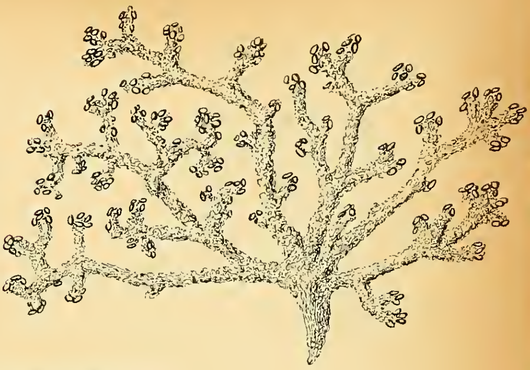
Observers differ on the nature of the lichen associaion. Some feel that it is purely incidental. Others think hat the partnership is of mutual importance, with each artner contributing to the community and each taking hat it needs. Yet others claim that lichens are examples f mutual parasitism. It would seem reasonable to asume, from the success of the combination, that there is balanced relationship—in other words, a state of peaceful coexistence." There are advantages to this ort of existence; but it is not necessarily the most sucessful kind of society, as we shall discover.

WHILE the fungus-alga relationship has probably been established since the emergence of living hings from the sea, it has been recognized by man for ss than a hundred years. In 1868, Schwendener anounced that lichens were really a society of living hings, but his revolutionary idea was not immediately ccepted. In 1889, Bonnier—who had faith in Schwenener's idea—succeeded in bringing together "wild" lgae and lichen fungi to produce artificial or synthetic chens. It was early noted that, while the algae and fungi ved in close proximity to each other, the fungi did not enetrate, harm, or destroy the algae on which they were ependent. The reason, or reasons, underlying this rearkable aspect of plant association have never been xactly determined. One of the most interesting features f the association, though, is the obvious preference of ertain species of fungi for certain species of algae (if e may be here permitted to use the word "preference").

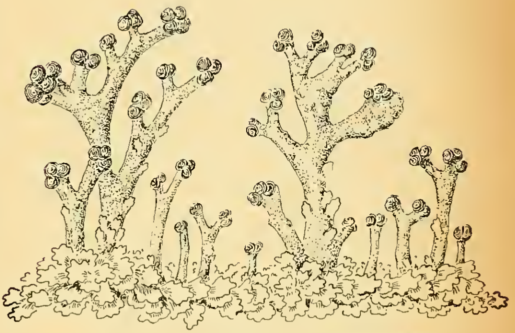
The body of a lichen is basically that of the fungus volved in the association. Generally, there are two yers to the body tissue—the outer and inner—and the lgae may either be confined to one or the other of these yers, or scattered through them. Three general body pes are recognized. These are the crustose, in which e general form is ill-defined, except that a portion may nter the support on which it rests; the foliose, which ossesses definitely recognizable holdfasts, and is a plant ody in many respects like that of a liverwort; and the uticose, which is erect, branching, or hanging.

There are four different basic processes that lichens ay go through to reproduce themselves. One is indiated in the accompanying chart section, where we use e term "sod flakes." Sod flakes are merely small units at may or may not be united, and which either grow dependently or associated with other units in the soil. ach of these flakes may be considered an independent lant, and bits of this basic tissue may become sepaated to establish other independent plants merely by ivision. This, of course, represents the simplest kind of production. Each segment of the original tissue has its ecessary complement of algae and fungi.

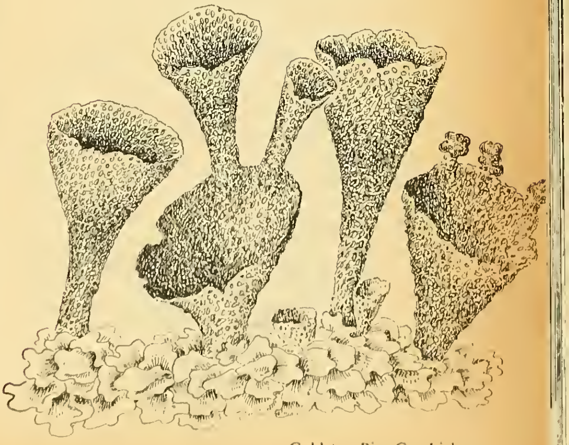
Another and probably unique sort of reproduction,



Pronged Easter Lichen



Red Crest Lichen, British Soldiers



Goblet or Pixy Cup Lichen

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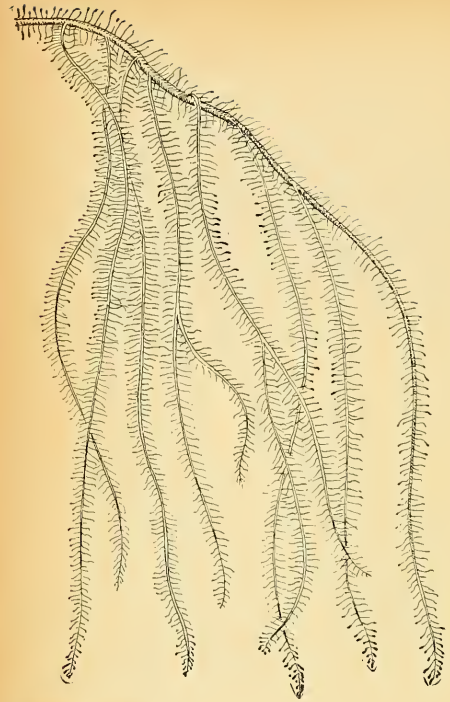


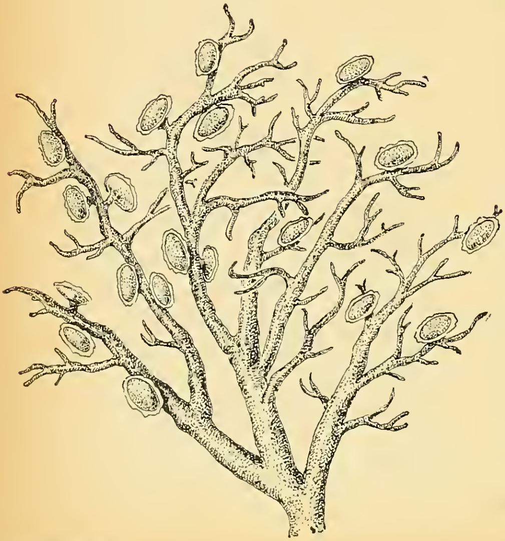
Long Beard Lichen

common among the lichens, is accomplished by structures that free little tangled masses of algae *and* fungi, which are ready to start new lichens when they reach a suitable location. The structures that free the little bundles of these two kinds of plants are known as soredia. Reproduction by soredia is only a short step from reproduction by fragmentation, since this latter process is merely the separation of small units of the algae and fungi essential to a particular lichen.

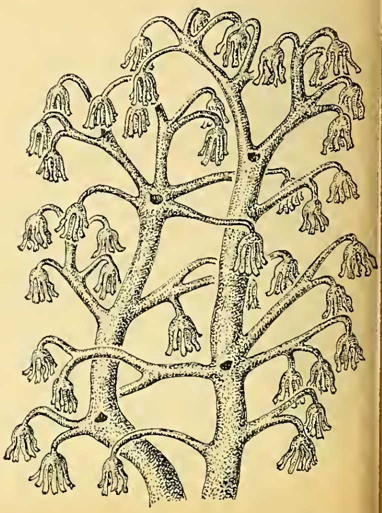
In both vegetative reproduction and reproduction by soredia, the close association of the algae and fungi is never interrupted. Many lichens also display structures that give the impression that they *should* be reproductive—as they are. These may be discs, cups, knobs, or other forms, which may either be hidden or held erect by branched or unbranched, colored or uncolored structures. Botanists call these apothecia. Although technically they are not true "fruits," these parts are commonly referred to as fruits, and we will do so here.

In this type of reproduction, the fruits are primarily structures that produce fungus spores. They do not necessarily produce the algae. Fungus spores may be freed independently of the algae, and success in producing a new lichen is dependent on contact of the fungus spores with the proper algae. It might appear that this sort of reproduction leaves much to chance, but it is successful. Once a new lichen or colony of lichens is established, it may exist for many years.

There is also a fourth kind of reproduction among the lichens—one that is seldom observed by any but the professional botanist. This is a true sexual reproduction, and concerns only the fungus part of the lichen. It is not common to all kinds of lichens, and is probably absent in most. In this case, procreation involves structures capable of producing real sperms and eggs. (Incidentally, the sperm cases are cast off and act as sperms, as in some



Gold Eye Lichen



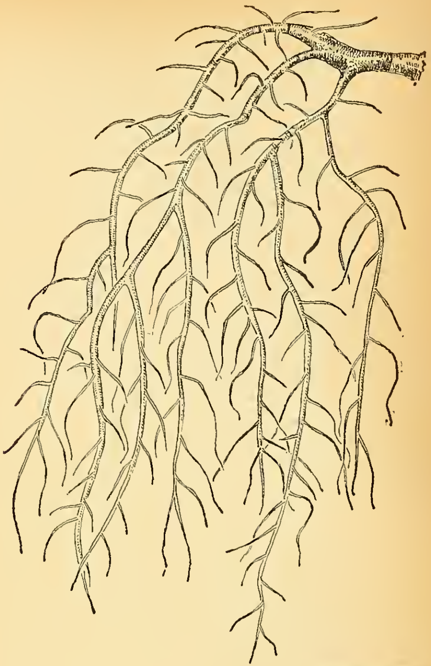
Reindeer Moss

of the red algae that were discussed in the 38th and 110th numbers of this educational series.) The female structure in this type of reproduction also has some characteristics in common with the female reproductive scheme in some of the red algae. Here, however, we have only the space to indicate that sexual reproduction does exist in the lichens; we must leave the exact details to a good botany text.

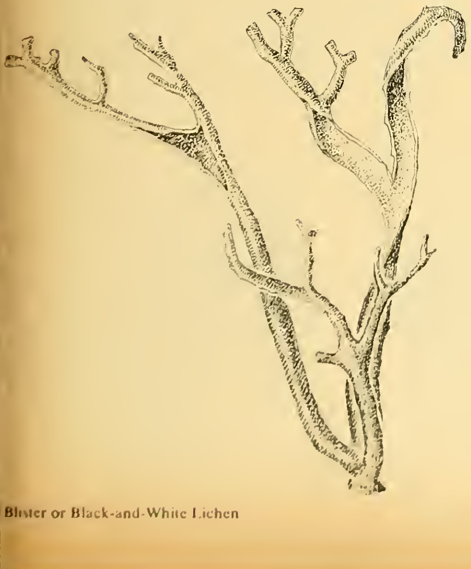
In certain respects, the life-history of a lichen may be difficult to decipher. A lichen may lie dormant for a few days, for weeks, months, years, or possibly decades, and then resume its normal life activities when the conditions of its environment again become suitable. Parts of the lichen may die, leaving other parts to grow and develop perhaps as separate plants. Who can say where a lichen's life-history begins or ends in such a cycle?

WHATEVER the locality, there is a definite seasonal growth activity in the lichens. This activity may be outwardly indicated by a change in color of the plant, easily observed at a glance. The presence or absence of water may in some cases be of greater influence than temperature in promoting growth but, generally speaking, lichens in temperate regions exhibit more growth activity during late fall and spring than during the summer. Physical changes are so small in a single season that, unless some kind of a marker is employed, dimension changes may not be immediately apparent.

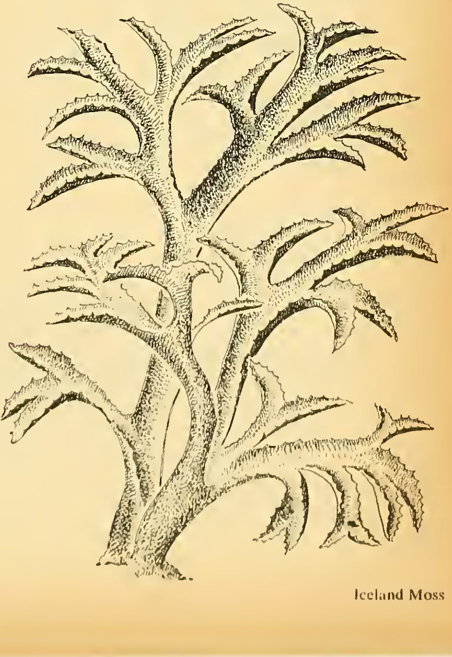
There is little doubt that the life span of a lichen is largely influenced by its immediate environment. When conditions change to allow rival plants to thrive, the life span of a lichen may be relatively short, since it cannot survive severe competition. Where competition is slight or non-existent, there is little to prevent a lichen from living for hundreds of years. For example, the life span of a lichen growing on a tree trunk would obviously be shorter than that of one growing on the surface of a



Old Man's Beard



Blister or Black-and-White Lichen



Iceland Moss

glacial boulder, where only minor changes take place over long periods. Biologically speaking, lichens in general may be considered as successful pioneer and frontier plants. They are not particularly "aggressive," but they readily move into areas where their kind has not existed before. There are few places in the world where lichens are not found. They exist on the highest mountains, and at the edges of the seas. They are found at the tops of the highest tropical trees, where the blazing sun is too strong for competitors; or they may be found at the bottom of the same trees, where other plants are ruled out by excessive shade or moisture.

Certain chemicals are produced by the lichens that can dissolve the constituent minerals of solid rock. The plants are thus enabled to occupy territory forbidden to other plants. The rootlike holdfasts of lichens are not true roots, but they can penetrate solid rock to a depth of a few millimeters, and if there is a crack or crevice in the surface of a rock, lichen "roots" are able to move in to even greater depths, and take hold firmly.

As soil-makers, lichens perform a most important function. Water, penetrating the tiny crevices produced by lichen roots, freezes and wedges out rock particles, contributing to the manufacture of new soil and the renewal of old. When a lichen dies, its decayed body helps enrich the soil, perhaps to the point where the soil may sustain other plant life. Lichens may sometimes serve as indicators of the nature of soils. Many mountain rodents and many Arctic birds of prey select elevated perches from which they may scan the countryside for possible food or enemies. In such places they deposit body wastes with a high nitrogen content. The wastes accumulate in considerable quantities over long periods. Frequently such animal resting places become the habitat of particular lichens. The lichens may then be used as food by some rodent that enriches the meager soil of the site, to permit an even more luxurious growth.

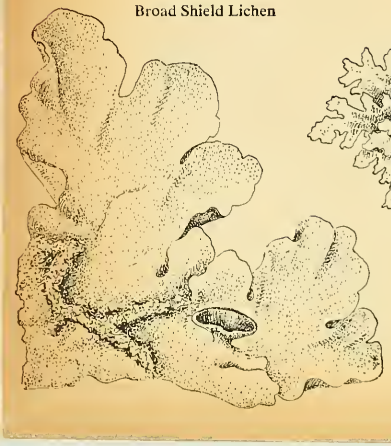
The basic nature of underlying rock formations in a particular locality may determine the kinds of lichens to be found. Some lichens prosper on rocks in which lime is an important chemical. Others do well on rocks that are granitic in character, and are basically acid. Lichens may also play a part in controlling the erosion of soil particles by wind and flowing water. A lichen blanket over an accumulation of soil particles prevents, to a considerable degree, the displacement of the particles. Such soil anchorage stabilizes the soil and helps delay excessive water runoff, moderating stream volume.

Superior to most other plants in their ability to survive difficult conditions, the lichens may become the dominant, and perhaps the only, vegetation over great tracts of land. They may thus allow the existence of animal life —including human life—in the more desolate areas of the world. For example, the Laplanders are almost wholly dependent on lichens for their sustenance in an interesting and indirect way. The basis of the Lapp's existence is the reindeer. Reindeer hides are used in making clothing and tents, the bones form implements, the flesh and milk are used as food. And the reindeer feeds almost exclusively on the lichens that cover that barren land both in summer and winter.

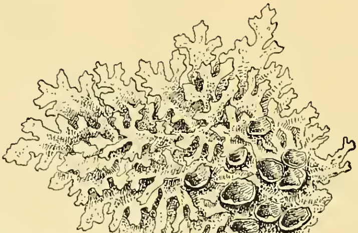
In the past, the Arctic has yielded an abundance of fur. Today, competition from substitutes has lessened the value of natural furs, but there are still many people in the world who derive a substantial part of their income from the sale of wild animal pelts. Few fur bearers eat lichens directly, but the fur bearers feed on lemmings and other rodents, which in turn feed largely on lichens. Even man makes use of some of the lichens, such as Iceland moss, as food, and others have been used as a survival ration for lost humans.

The Greek philosopher Theophrastus, who lived about three hundred years before Christ, wrote about old man's beard lichen. In earlier days, the lichens were investigated more for their potential value as dyestuffs than for any other reason. Certain lichens have been used as a source of dyes for fabrics; but, unfortunately, the colors are not always permanent when exposed to light. Other lichens, in the genera of *Roccella* and *Lecanora,* yield archil, a dyestuff sometimes known as cudbear, that produces blue, red, and violet dyes that are used in medicines and drinks. Early botanists used the plants to illustrate to their students how inorganic rock could be turned to organic plant material.

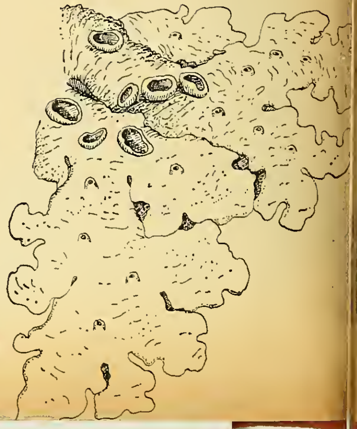
Litmus, which turns red when exposed to acid and blue when exposed to alkali, comes from the lichens of the genera mentioned above. As a commercial substance,



Broad Shield Lichen



Boulder Lichen



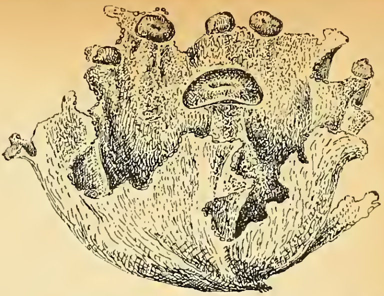
Spreading Leather Lichen

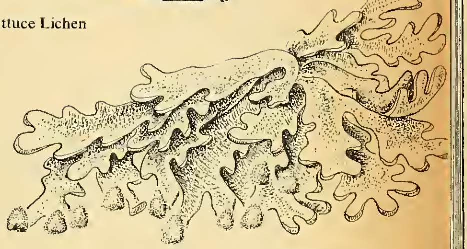
litmus appears as a lumpy, blue mass, which is obtained from the lichens by exposing them to air in the presence of ammonia, potassium carbonate, and other chemicals. Litmus is used in chemistry as an index of acidity or alkalinity, and the proper use of soils, determined in part by litmus tests in which lichens are thus involved, is of great national economic importance.

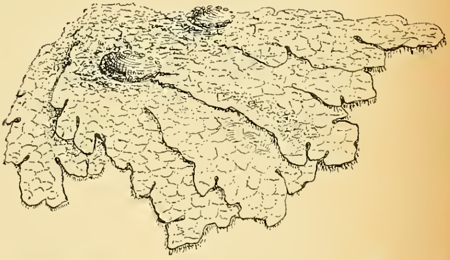
Quite aside from the practical uses of the lichens, the plants appeal to man's sense of beauty, and now and then to his superstition. In times past, it was the custom of medical men to assume that the dog lichen had value in the treatment of hydrophobia, because the spore-producing parts of the plant resembled a dog's tooth. This, of course, would be considered ridiculous today. The little pixy cups that may be found at times scattered about on the surface of poor soils were reputed to have been the goblets used by the little people. Charlatans could always be found who would interpret the results of such meetings to the credulous—undoubtedly to the advantage of the interpreter. This was obviously pure fantasy, but perhaps fantasy had and still has its merit in a world dominated by grim reality.

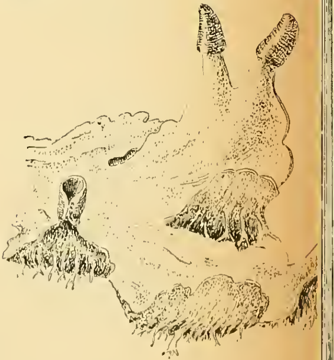
The use of lichens as medicines has passed, for the most part, into limbo; but an old prescription for the use of *Peltigera* in the treatment of mad-dog bite might be recited here. It reads: "Patient is bled and ordered to take a dose of *Peltigera* in warm milk for four successive mornings thereafter. He must take a cold bath every morning for a month, and for two weeks subsequent, a bath three times a week."

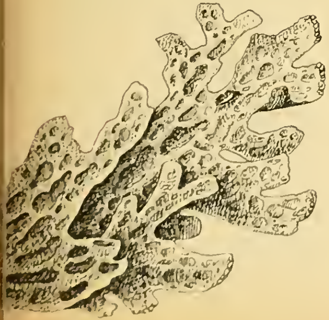
In summary, it has been shown that there is a state of coexistence between two different kinds of plants—the algae and the naturally parasitic fungi—and that the condition is profitable to both the plants involved. Some botanists do not believe that this relationship is one of true coexistence, and claim with some basis in fact, that the relationship is rather one of mutual parasitism. Whatever the truth may be, however, the association is a workable one. In the past hundred years, we have undoubtedly gained more real understanding of the nature of lichens than we had acquired in the preceding twenty-three centuries. Who knows what the next century of study may bring in this wide field of investigation?

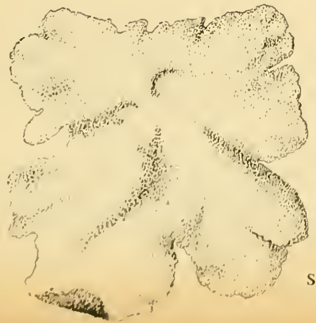

Lettuce Lichen


Puffed Shield Lichen


Stane-Raw Lichen


Dog Lichen


Lung Lichen


Smooth Rock Tripe

	VEGETATIVE PART OF PLANT	LICHEN REPRODUCTION
Goblet or Pixy Cup Lichen *Cladonia pyxidata*	A mat of sod flakes, each to 1/5 inch long, rounded, lobed or simple; gray-green to pale gray or brown surface, with undersurface white, grayish, or tinted with grayish brown. Flakes overlap to form essentially flat structure, but flake tips are free, are slightly raised, and may stand almost erect.	Green-gray or brown stalks arise from central part of flakes to 2/5 inch high, ending in goblet or cornucopia shape, or may be erect, strap-shaped, forked 1 to 3 times. Goblets may bear other goblets from rim; these in turn may bear similar goblets. Stalk hollow, with flaky surface that may shed portions.
Red Crest Lichen, British Soldiers *Cladonia crystatella*	Sod flakes, scattered or closely crowded, are greenish gray or straw-colored when dry, each to ⅛ inch long and wide, but often half this size or even less, with margins toothed or rarely lobed and divided. Is described as having a coral-like vegetative base.	Fruiting branches to 1-inch tall and conspicuously coral-like, but often covered with sod flake scales. Sometimes tree- or coral-like with radiating branches, uniting above to form a cup or tray. Surface smooth or warty, greenish gray, white, or slate-colored, with rind and variable branches.
Reindeer Moss *Cladonia rangiferina*	Appears shrubby with profuse branching. The basic initial thallus is rarely found or seen, being almost completely hidden by the tall branching tops of the stalks. Basic crust or sod flakes are like a gray granular crust lying close to the ground. This crust soon disappears as the tall structures develop.	Grows to 4 or more inches tall, with stalks to 1/10 inch in diameter but usually less, profusely branched. Tips commonly turn downward and are profusely and repeatedly subdivided. Surface like felt, but older stems may be mealy or warty, ashy white or sometimes tinged by greenish straw color.
Pronged Easter Lichen *Stereocaulon coralloides*	A primary thallus is replaced by a profusely branched structure to 3 inches high. The basic thallus comparable to the sod flakes of the cladonias described, may disappear, but just where the one begins and the other *ends* is not well defined. Coral-like branches are slender, compressed cylinders.	Branches are smooth and naked in the lower areas, sea-green or ashy, with a brownish cast. Surface appears warty and is spotted with very short-stemmed discs that are borne at or near the tips of the coral-like branching structures. These discs comparable to "cups" of previously considered species.
Old Man's Beard *Usnea barbata*	Vegetative structure is shrubby, frequently hangs from some support, and is highly flexible. To 20 inches or more in length, covered with numerous radiating structures colored like main axis, and not always easily distinguished from the basic structure. Branches circular, finely roughened.	Basic structures may be a greenish gray that blackens with age, or tinged with red. Commonly paler at the tips, becoming straw-colored there. Structures including algae and fungi may form soredia on older tissues and be freed, forming new plants if they fall on territory suitable for development.
Long Beard Lichen *Usnea longissima*	Sometimes considered a subspecies of *U. barbata*. But *U. longissima* has longer, if relatively few, main branches. These are covered with branchlets that commonly radiate at right angles and are not usually tangled. Branchlets may be approximately 2/5 inch long.	The surface of branches is covered with fine, flat scales or loose materials. This surface may look scabby because of the covering scales. This species is considered here as an example of how variable these plants are and how close integrations may be found among otherwise recognizable entities.
Gold Eye Lichen *Teloschistes chrysophthalmus*	Highly variable. While *Usnea* has cylindrical branches, *Teloschistes* has flattened branches, and while the related *Ramalina* has branch tips that are blunt or pointed, in this genus the tips end in fine hairlike structures. *Ramalina* is also much smaller. Yellow to pale, greenish gray with yellow tinge.	May appear as hanging threads to 2 inches long, easily spotted because of yellow color. The algae are *Protococcus,* which appear as simple green spheres under the microscope. Plant seems to be profusely branched, but is more rigid than some close relatives.
Blister or Black-and-White Lichen *Physcia leucomela*	Surprisingly uniform, strap-shaped, irregularly forked strips, to 1/12 inch in diameter. Edges turn inward and downward and bear ragged looking, blackish hairs. Tips are not especially blunt and are usually carried in dense tufts to nearly ½ inch across. Blackish hairs more or less opposite each other.	Upper surface is gray or whitish and undersurface is white, with some down on it, the white contrasting conspicuously with the black marginal hairs among which may be soredia-yielding algae and fungi that may then be freed to establish new plants. Some species form flat rosettes rather than tufts.
Iceland Moss *Cetraria islandica*	Found in tufts or tangled masses to 2 or more inches high, with a pronounced tendency when drying to form something like a spine-edged trough. Sometimes found in paper-thin forked stalks to over ⅛ inch wide. All forms tend to curl when drying, giving them a highly variable appearance.	Surface is olive-green, but brown to gray when dry; it is commonly smooth but may be ridged or wrinkled. Undersurface is paler than the upper and may bear, near the branch bases, gray patches of soredia that serve a reproductive function independent of fruits.

FUNGUS REPRODUCTION	WHERE FOUND	ECONOMIC VALUE
Fruits brown or purplish, to 1/6 inch across, borne on tips of goblets. Some related species have bright-red fruiting structures. Goblet tips may be closed by false bottoms not necessarily of reproductive significance. Fungus spores fall, are distributed by wind, and become associated with algae.	Formed on ground, sod, logs, or rocks, and most abundant in regions of limestone rocks. Closely related to taller reindeer moss and the red crest lichen. Found frequently throughout the United States and with world-wide distribution outside the country. A most cosmopolitan plant, easily recognized.	Useful in furthering disintegration of rocks and soils, in anchoring loose particles from wind and water erosion, thus helping to build up soil volume. Associated in folklore with pixies—mischievous sprites reputed to enjoy leading people astray and getting them mentally confused, hence "pixilated."
Fruiting bodies over swollen tips of branches, globular or lumpy, to ⅛ inch through. Usually scarlet, but may be maroon, black, buff, orange, or even white. Fruiting structures on practically every branch tip. Bright colors may attract insects, which may be instrumental in distribution of the spores.	Common in fields, woodlands, and along the roadsides on soil, rocks, tree bark, fence rails, and deadwood, but most frequently considered as being found on latter. Ranges throughout eastern United States, but apparently unknown in the American west or Europe, where *C. bellidiflora* replaces it.	Of no major economic importance. Probably most easily recognized of all of the cladonias. Serves as a soil-maker and anchor, and as slight flood deterrent. Most popular for transplanting to indoor terrariums. Name "British soldiers" doubtless refers to apparent resemblance to redcoats of soldiers.
Brownish fruits to 1/25 inch across appear as knobs on the tips of some of the fruiting branches. Tangled masses of whitish algae and fungal threads may be found in lumps along older stalks or may be inconspicuously scattered on feltlike surface. These may start new plants on suitable territory.	Found on thin layers of humus over rock surfaces in the open, under trees, or growing from rock crevices. Common under pines and other cone-bearing trees. It is widely distributed through North America, particularly in the north, and similarly distributed in Old World, often forming climax area.	Of considerable economic importance as basic food for reindeer and other animals of the habitat. Despite bitter taste, it may have some subsistence value as food for man, or as something to mix with sparse supply of flour to extend a diminishing food supply. May serve as Scandinavian famine food.
Discs are at first brown, surrounded by lighter or whitish area that becomes obscured with age. Algae are completely meshed in threads of the fungus. Unlike hollow stalk found in *Cladonia*, the stalk here is solid and not brittle. Possibly *S. paschale* with profuse branching is more representative.	Grows well on a thin humus layer over rocks. It is considered by some to be a subspecies of the common *S. paschale*, which has a wider distribution. This latter species is found from New England to South Carolina in mountainous areas, north through Canada and Alaska, Europe and Asia.	This lichen is of no great economic importance, but it serves as soil-maker and soil-anchor, thus delaying erosion. It may reach a height of about 3 inches and could have some nutritive value as food for animals that graze in the area, but this is hardly substantial.
Fruits are seldom seen. They are usually small—up to ¼ inch in diameter—and are distributed about the plant rather than at the tips. The fruiting disc is pale gray to buff and may have hairs drooping from its borders. Some close relatives have short, stiff, erect stems, while others are flexible.	Grows most commonly on tree bark or dry deadwood in mountainous forests. It is commonly associated with swamps, though actually it does not grow in the water itself. Grows on living or on dead plants and is found throughout North American continent and wherever conditions are suitable.	This lichen is of no particular economic importance. However, in the days when medicinal values were determined by the resemblance between plants and parts of the human anatomy it was believed that *Usnea barbata* yielded substances that stimulated growth of hair.
Fruiting structures are rarely found, but when present are near the tips rather than distant from them, as in Old Man's Beard. A related hairlike *Usnea, Usnea trichodes*, has few secondary branches, and these are smooth rather than rough. Most lichens have subspecies or varieties as relatives.	Found hanging from trees and other supports in areas similar to those occupied by Old Man's Beard, especially in the north. General aspect of all hanging lichens is affected by stiffness and position of the radiating hairs, by the disturbances caused by wind, and by character of supporting plant.	Probably of little if any economic importance as food for animals, let alone as fiber, as cover, or as a source of dyes. Some day a use may be discovered other than that of confounding botanists or of creating arguments among those working at classifying.
Fruiting structures appear as stalked discs to 1/5 inch in diameter. Edges torn or toothed from which radiate finer hairlike structures, orange or conspicuously yellow. Undersurface is normally ash gray. Common name "gold eye" describes fruiting body.	Most commonly found on trees or old wood, and ranges in one form or another into all parts of North America as well as in the major continental areas of the world. Some related species, as *T. parietinus*, are common on moist stone walls and trees along water.	Apparently of no economic importance, and of interest to most people primarily because of unique and attractive color and the interesting structure of the plant parts that support the fruiting bodies. In spite of its wide distribution, it is not ordinarily as common as are some other species.
Fruiting structures on short stalks are on branch tips, disc-shaped, frosted pale gray, with ragged whitish rim, to 1/5 inch across, yielding brownish, 2-celled spores. Fruit production is rare in the northern part of this lichen's range. Borders of disc may be lobed.	Almost always found on trunks and branches of trees with some related species growing on soil and some on bare rocks. This species is relatively common in the states of the southeast, yet grows as far north as central New York. Relatives range more to north.	Of no generally recognized economic importance, and probably does no great damage to the trees on whose bark the patches are most likely to be found. Species growing on rock may well stimulate soil production through furthering disintegration of the rock.
Fruits are borne along the tip margins in discs to 2/5 inch across, with dark brown rims torn or spiny. The spores yielded from these areas are seen under the microscope as colorless and undivided. Fruits are not technically fruits but are merely spore-yielding parts of the fungus part of the lichen.	Found on rocks and soil in appropriate sites through northern United States and Canada, as well as Alaska. Plentiful along coastal regions of New England, but to the south may be in isolated patches at higher elevations. Not easily confused with other lichens of its range and habitat.	Possibly our most important lichen in terms of value for direct consumption. Serves as useful fodder for wildlife and cattle and may even be eaten by man for its abundance of starch. May grow interspersed with patches of reindeer moss but is not easily confused with it.

	VEGETATIVE PART OF PLANT	LICHEN REPRODUCTION
Lettuce Lichen *Cetraria lacunosa*	Has general appearance of lettuce with irregularly broad-lobed and crinkled margins. Grows in tufts to 4 inches across and to a height from base of over 1 inch. Surface is pitted, giving plant common name of pitted cetraria; *lacunosa* refers to its saucer shape.	General color of plant is from pearl to slate, with white to darker underparts. Attachments to support of plant are few or weak. Soredia, which yield combined algae and fungi, are not so conspicuous as the fruits that yield only fungus spores. A net pattern appears over the shiny green upper surface.
Puffed Shield Lichen *Parmelia physodes*	Appears often as flat rosettes, to over 2 inches across, with free tips raised or appressed. Also spreads irregularly, often intermingling with other lichens and mosses. Its zigzag branching has margins that look like a series of fingers with puffed tips, which curl upward showing brown color conspicuously.	Puffed tips an important characteristic to notice as this distinguishes plant from most *Parmelia* species. Upper surface smooth and greenish gray; undersurface black, but shining brown and wrinkled at tips. Tips sometimes break open giving plant a flower-like appearance. Pale blue, mealy soredia.
Stane-Raw Lichen *Parmelia saxatilis*	Flat rosettes grow to 4 inches or more across. Greenish-gray surface has a fine network of pits and wrinkles; undersurface is black with a dense mass of rootlike hairs that are matted to the margins, which are cleft by narrow, wavy lobes. Surface is usually shiny.	Presence of true soredia is questioned by some authorities, while others claim they are found in a narrow white line that runs along the margins. In any case, both the nature and the presence of soredia are matters that must remain to be determined by further research.
Boulder Lichen *Parmelia conspersa*	Appears in mats to over a yard across, which may be anything from a single plant to a colony or community of plants. Branches may remain separate from those adjacent, or may grow over them, but they usually lie close to the supporting rock. Border of plant usually lighter in color than center.	Upper surface is gray-green to yellow-green at border, but center may be olive-green to dull-gray and even black. Undersurface of plant is chocolate, often turning black. The holdfasts are relatively few and are dark and rootlike. Soredia that yield fungi and algae may appear in clumps.
Broad Shield Lichen *Parmelia perlata*	Greenish yellow to slate color. Upper surface has reddish-brown border that tends to roll upward showing the brown lobes in sharp contrast with the normal upper surface color. Black undersurface is smooth or delicately wrinkled. Lobes lack hairs on margins.	Upper surfaces of lobes may be covered with whitish masses of soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, *Marchantia*.
Spreading Leather Lichen *Sticta amplissima*	May appear in flat rosettes to over 1 foot across, with wavy margins or branches to 2/5 inch across; these branches are usually divided into narrower units, also with wavy margins. Upper surface is usually smooth, often with narrow wrinkles; pinkish gray or pearl-gray when dry, green when wet.	Undersurface is downy and pale brown at the margins and reddish brown toward the center. It frequently becomes blackish with age, when it acquires—as does the rest of the plant—a generally leathery appearance. Soft hairs may cover the bottom or underside, but the upper surface appears smooth.
Lung Lichen *Sticta pulmonaria*	Appears as irregular rosettes to 1 foot across, with branches to 2 inches or more in width, each ending in angularly tipped lobes. Color ranges from pale-green and gray-green to brown or, when dry, black. Surface pitted to depths of 1/6 inch and marked by network of ribs, often with lifted margins.	Soredia including algae and fungi are dusty-gray and appear along the lifted margins or along the ribs. The tissue is so thin that the undersurface may appear like the reverse of the upper surface so far as ridges and wrinkles are concerned, with grooves becoming ridges and pits becoming bumps.
Dog Lichen *Peltigera canina*	Rosettes sometimes as much as 20 or more inches across, with smooth, leathery brown or gray upper surface, which becomes green when moist and turns blackish in winter. Undersurface is covered with a network of thick white veins that, with age, become brown, then black. Holdfasts abundant.	Upper surface has no prongs or soredia that free algae and fungus spores. Algal cells of the symbiotic relationship are *Nostoc* or *Gloeocapsa*, not *Protococcus* as in so many lichens, and these are not freed through conspicuous soredia as in many other species of lichen.
Smooth Rock Tripe *Umbilicaria Dillenii*	Leathery sheets, wrinkled and irregularly twisted, are attached to rock or base by a single central holdfast, unlike the many holdfasts found on many lichens. No regular lobes, but margin may be ragged. Upper surface may appear powdery; is olive-green when moist, grayish brown when dry.	Lower surface covered with a ragged, black felt; some related species lack this velvety undersurface. Near the major point of attachment may be weak branching strands that seem to serve as secondary attachment. Algal cells involved in the lichen are *Pleurococcus*, resembling *Protococcus*.

FUNGUS REPRODUCTION	WHERE FOUND	ECONOMIC VALUE
Brown fruits to 2/5 inch across arise frequently from margins of upper leaf surface. Sometimes those fruits on short spurs with smooth thin rims may have a large irregular central hole that gives the pitted effect. These fruits yield undivided colorless spores, which serve in distribution of the lichen.	Relatively common on tree trunks and twigs, most common in swamps. It is found throughout the mountainous parts of northern United States as well as in Alaska and Canada, but is not common south of Canadian border states. Apparently not known outside of North American continent.	Of no conspicuous economic importance but might be of food value in serious crises. Of interest to botanists, though, for research on algae and fungi. Algae involved in the lichen are *Protococcus*. The fungus is an Ascomycetes, as apparently all lichen fungi are.
Fruits, on elevated spurs, are uncommon to rare, appearing as saucers to 1/6 inch across and with irregular rims. The fruits may bear soredia that yield spores and algae on underside. There are many closely related species with minor but significant differences.	Commonest on dead limbs and twigs of pines and hemlock, lightly attached but sometimes completely encircling a small twig. Ranges through northern United States, but is more plentiful in mountainous areas. Superficially resembles a liverwort like *Marchantia*.	This lichen is of no recognized economic importance or significance in relation to other organisms, but it presents a distinct challenge to taxonomists, who find confusion in close relationships between species of *Parmelia*, not all of which are clearly separate.
Fruits, or the fungus reproductive structure, are not commonly seen. They consist of deep, brown saucers with roughened, warty, often prong-covered rims. Spores are undivided and colorless. Confusion as to soredia may give rise to problem of identifying species.	Found on bare rocks, earth, deadwood and bark of living trees, in a variety of places including swamps, highlands or ordinary woodlands. Its range extends through northern United States and into Canada, as well as over all major continental areas of world.	Of little, if any, major economic importance, but may serve as a minor soil-anchor and as a soil-former through disintegration of supporting rocks by action of its holdfasts. Has been suggested as an emergency food but is recommended only in dire emergency.
Fruits of fungus are saucer-like, regularly or irregularly lobed, sometimes dark brown, purplish or greenish, with rims either smooth or toothed and to ½ inch across. Spores yielded are colorless and undivided, and may be distributed by wind. Some related species distinguished by color differences.	One of the commonest of all of the paper-like lichens found on rocks. May cover cliffs, old monuments, and stone walls, but distribution is not limited to shady spots, as it may be found even in most exposed spots. Common in northern United States and Canada, in mountains to south, and elsewhere.	Of little, if any direct economic importance, but may serve role of helping in disintegration of rock and the forming of soils or even in controlling some erosion. Whatever its value, the changes effected are discouragingly slow, although must be recognized.
Fruits rare, but may be to ½ inch in diameter, shaped like shallow saucers, stalkless or short-stalked, with chestnut-brown centers and thick, smooth rims. May split down center at maturity and may be greenish brown under some conditions. Spores undivided, colorless.	Usually found in shaded spots on rocks, and commonly on tree bases. Range extends throughout highlands of northern United States and into Canada; more common in the northern part of its range than to the south, although usually not in extreme Arctic areas. Found in major continental areas.	Of little recognized economic importance. This species is, however, a center of controversy between chemists and botanists, the chemists claiming that chemicals can distinguish separate species, while botanists claim no significant botanical differences exist.
Fruiting bodies of the fungus are light-red when young, brown at maturity, and black with old age. Abundant on upper surface, they are shallow, saucer-shaped to ⅛ inch across, crowded, or irregularly scattered. When immature, the fruits appear as hemispherical warts with red centers near lobe tips.	Found on rocks or bark of usually large trees throughout the eastern part of the United States, particularly in swamps; most abundant on cedars in cedar swamps. Known throughout eastern United States and on major continents of world except South America.	Of no major economic importance that is recognized. The species name, *amplissima*, refers to its rather large size. Color changes due to wetness and other factors may have significance, as yet undetermined. The algae in this lichen may be *Nostoc*, not *Protococcus*.
Fruits are uncommon. When found, they are disc-shaped, to 1/6 inch across, close to margins on the upper surface, and are reddish brown, or darker with age. Algal cells are *Protococcus*, distributed from soredia described above. Mature spores colorless.	Most common in mountains of northern United States where it grows on trees and on limestone rocks. It may extend farther south than some of its close relatives. It is also common in the western part of the country and is known in all major continental areas.	Formerly was considered as valuable for the production of a drug used in correcting diseases of the lungs, but it is not listed now in official drug encyclopedias. When ground up and mixed with dough it is reputed to act like yeast, but property is questionable.
Fruiting bodies are borne on the raised and curved tips of lobes along edge of the plant body; these lobes curl backward, somewhat in form of a dog's tooth. Spindle-shaped, colorless spores are about 4 times as long as wide, and sharply pointed at ends. Mature in fall, they are renewed in spring.	An extremely common lichen, found mostly on the ground, on rocks, or tree bases; though seen in open spaces, does best in deep woodlands and along stream banks. When mature, the "dog-tooth" edges curl back, exposing underside and making a hood over the sheltered spore producers.	When medicinal usage was determined by resemblance of a plant to another object, this lichen was said to yield medicines effective in combating maladies due to dogbite, but this superstition finds no support today. Practical economic value is about nil, although plant can anchor soil and erode rock.
Major reproductive technique is by fragmentation of the plant and through undivided, colorless spores that are produced by rare button-like structures borne on the upper surface. These black structures are often covered by irregularly branching furrows, which appear blister-like in some species.	This rock tripe is relatively common on boulders, cliffs, and exposed rocky surfaces through most of the central and eastern United States. It is usually to be found at higher elevations, but it is also known to grow below 1,000 feet elevation in the northeast. There are many closely related subspecies.	Major importance is in disintegration of exposed rock surfaces, thereby assisting in making soils and delaying the runoff of water that falls on the site. It is reputed to be of value as food, but taste—which repeated boiling is said to improve—is such that it could only be eaten in emergency.

nature IN THE SCHOOL

The lichens are often found in schoolrooms and studied in school programs. They commonly appear in school terrariums, and are sometimes used to brighten up classroom corners. Outside the classroom, lichens may be discovered on the foundations of school buildings, on the bark of schoolyard trees, or on exposed stones in the school rock garden.

In developing a school or classroom terrarium that is to include some of the lichens, it is best to do some planning. For example, it would be well to include at least one lichen-covered stone as an example of the pioneering tendencies of the lichens in developing new territories; it will also serve to point up the part that lichens play in the prevention or delay of soil erosion, as mentioned in the accompanying article.

There is little point in trying to plant a lichen or lichens on bare stone, since success is not likely; and, of course, there is no point in asking a seed store for lichen "seeds." Lichens do not produce seeds. However, it is fairly easy to establish lichens in a terrarium, since they have no true roots. The best way to transplant a lichen is to bring it to the terrarium on a piece of sod, in which plant adjustments have been made and can be examined.

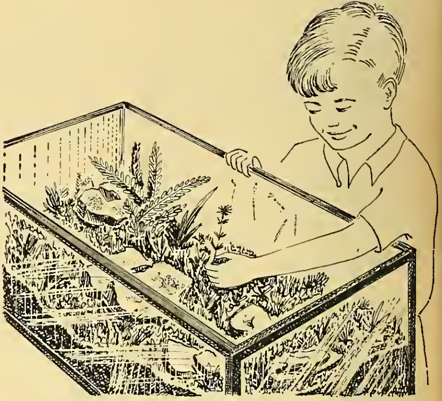
Examine the list of eighteen lichens that accompanies this insert, and see how many of the plants can be collected and installed in your classroom terrarium. It is highly unlikely that a student could secure all of them; and even if he could, they would not all thrive in a single, small terrarium. Thus it might be worth while to have three or more terrariums. One could be a "dry" terrarium, in which lichens of relatively dry habitat could be exhibited. A second might be a "wet" terrarium, for water-tolerant species. A third might be used to exhibit lichens that grow on the bark, twigs, or other parts of trees. In this latter might be included a small section of a lichen-covered fence rail or log. In any case, a record of the specimens' original habitat should be kept, and an attempt should be made to duplicate as nearly as possible the conditions of water and light that obtained in the original locality.

It would be well to collect a few specimens for a herbarium, in order to supplement those of the terrarium. Most lichens lend themselves reasonably well to drying, but some have fine structures that are best preserved in a liquid. Highly diluted Formalin or somewhat diluted rubbing alcohol may answer this latter purpose. However, it should be kept in mind that alcohol may remove some of the coloring matter of a lichen, an important point where plant color is vital for identification.

It might be interesting to make miniature collections—not of whole lichen plants, but of units merely large enough to be easily identified. Such a collection might include some lichens found growing on tombstones in old cemeteries, with data indicating the possible age of the plants as deduced from dates on the headstones. It may be surprising to see how the lichens on tombstones that have been in place for a half-century or more differ from those that have been growing for a mere decade.

If a schoolyard tree exhibits lichens growing on its bark, it will prove interesting to drive in a row of small brads around the edge of the plants, taking care to see that none of the nailheads are covered by the lichens. Make a record of the date of the operation, and keep it in the schoolroom for future reference. During the following year, a new set of brads may be driven around the same lichen, and in this way the growth of the plant may be easily measured and recorded. If iron brads are used the first year and copper nails the second, it will be easier to distinguish the growth of the plant. You may find the growth rate a matter for surprise!

It might be interesting, also, to make some color sketches of various available lichens. The student might try to explain why the green areas of the plants are usually found exposed to the sun, while the white or black areas are not. He will notice, too, that the brilliantly colored parts of the lichens—like those of British soldiers—are found on the elevated areas of the plant where the colors might attract insects. It should be kept in mind that these brightly colored areas are spore-producing.


Lichens may be transplanted to terrarium for close observation.

In the chart section of this insert, we have often used the words "soredia" and "fruits," and we have explained in the text that the term fruits is really not used properly, because lichens do not bear true fruits. The latter develop from the ripened ovaries of flowers, which is not the case with the lichens.

It is surprising how often the lichens are mentioned in English literature and poetry. The student might start a scrapbook of such references for his own enjoyment. If a copy of Nina Marshall's *Mosses and Lichens* (published by Doubleday, Page and Company, in 1908) can be located, the student will find in it an abundance of useful references to the lichens, although the volume lacks somewhat in logical organization. When I graduated from high school in 1908, I saved my pennies and purchased a copy of this book—and have enjoyed it and profited from it thoroughly ever since!

GREAT NEBULA in Orion is classified as emission nebula ecause it emits its own light. This phenomenon is caused by unusually hot stars in masses of interstellar gas, dust particles. Stars' radiation renders the gas self-luminous.

SKY REPORTER

Photography and spectroscopy help astronomers survey the sky

By Simone Daro Gossner

WILLIAM HERSCHEL'S SUCCESSORS attempted to complete his survey of the heavens, extending it in par- cular to the Southern Hemisphere; but their studies did ot in any way improve the model of the universe that he ad derived from his own observations. This temporary alt in the progress of cosmology resulted mainly because ew modifications or improvements had been brought to ne design of telescopes since the days of Herschel.

The first half of the nineteenth century saw almost simul- neously the development of two techniques of observa- on: spectroscopy and photography. Some decades later, eir application to astronomy would lead to the first odern concepts of the structure of the universe. To this ay they are among the astronomer's most powerful tools.

Spectroscopy utilizes the fact that the atoms of a given ement (hydrogen, oxygen, iron, etc.) emit light waves certain frequencies only; this group of frequencies is fferent for each element and constitutes its *spectrum*. Furthermore, the relative strength of the emission at the various frequencies of the spectrum is a clue to the physical conditions of the element (particularly its temperature). When light coming from a star or other celestial source is allowed to pass through a prism, it is dispersed like a rainbow according to the frequencies of the rays that comprise it. An analysis of this composite spectrum reveals the physical characteristics of the source.

The invention of photography, by Daguerre in 1839, was not immediately applicable to astronomical research, because the early photographic plates were too slow to produce usable pictures of sky objects. When the first photograph of the moon was obtained, in 1840, it seemed a miracle that the image could be recognized at all. But with the gradual improvement in photographic plates, the astronomical advantages of this new process became readily apparent. The photographic process is a cumulative one; as the exposure time is increased, images build up, reveal-

Spiral galaxy is recognizable by its spiral arms winding around nucleus of tightly packed stars. Very hot stars and interstellar gas compose the arms.

Edge-on galaxy is probably a spiral but its plane coincides with the lin

ing progressively fainter objects and finer details. The human eye does not possess this capacity: no matter how long one looks at a star through a telescope, it will always have the same brightness. Therefore, astronomical photography is capable of recording celestial objects too faint to be observed visually with any instrument.

By the end of the nineteenth century, photography had become a powerful adjunct to astronomical research. Many existing visual telescopes were adapted to photographic use, and new ones were designed to serve exclusively as cameras. The optical system of the telescope (whether mirrors or lenses) plays the role of the lens in a conventional camera, and focuses the image on a photographic plate. Film is seldom used because it tends to shrink irregularly and is not very durable; a glass plate coated with photographic emulsion is usually preferred.

The most powerful photographic telescopes in existence today fall generally into two categories. Large parabolic reflectors permit the observation of extremely faint and remote objects, but cover only a very small area of the sky at a time. So-called Schmidt telescopes, consisting of a spherical mirror and a correcting lens, offer the advantage of a wide usable field. This wide-field characteristic makes them ideally suited for extensive sky surveys.

Less than a century ago, nebulae and star clusters were known to astronomers as hazy patches in the sky, with ill-defined outlines and barely distinguishable structure. Except for a few loose clusters of stars, it was generally impossible to determine whether the object under scrutiny was a stellar aggregate or an amorphous mass of nebulosity. The suggestion by Immanuel Kant and a few followers that some of these objects might be "island-universes" belonged strictly to the realm of speculation.

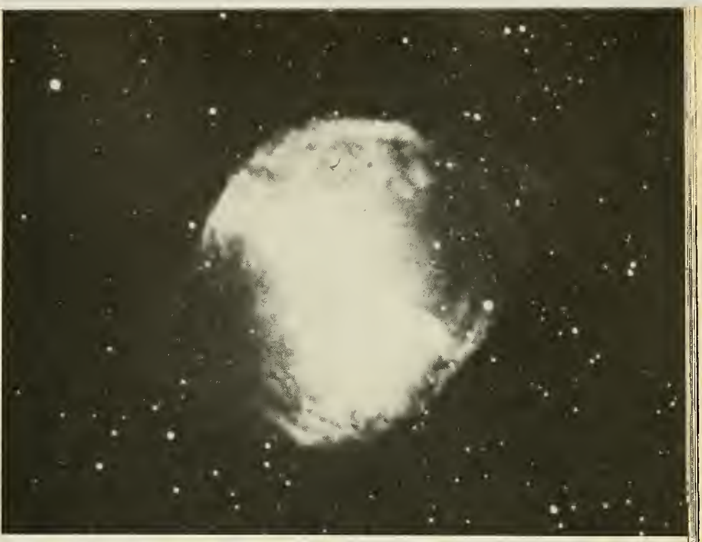
By contrast, observations with the large photographic telescopes have not only confirmed Kant's assumptions, but also have revealed the incredible variety in the shape, structure, and composition of the nebulae. On the other hand, powerful spectrographs attached to modern telescopes have made it possible to distinguish between true gaseou nebulae and remote stellar systems.

Gaseous nebulae are found almost exclusively along th broad band of the Milky Way, and arise in most cases fron the presence of vast amounts of interstellar gas (mostl hydrogen) and dust particles. When stars are embedde within this material, the loose particles act as billions o tiny mirrors, reflecting the starlight in every direction. I the embedded stars are unusually hot, the surroundin material is rendered self-luminous, that is, it emits its ow light. One of the most famous *emission nebulae* of this kin is the Great Nebula in Orion (see picture on p. 45), whic may be seen with the naked eye, dimly surrounding one o the stars in Orion's sword. If, on the contrary, there are n stars within the nebula, it may still be visible as a dar mass if it happens to be superposed against the backgroun of a more distant reflection or emission nebula (see Horsehead, at right, *below*).

A distinct category of emission nebulae comprises smal tenuous, shell-like objects, each deriving its illuminatio from a very bright central star. These gaseous shells ar known to exhibit turbulent motions. When viewed throug a small telescope, they appear not unlike the planets Uranu and Neptune; this fact has earned them the name of *planetary nebulae* (see Dumbbell, at right, *above*). About 75 of these planetaries are known at present.

Some of the objects, which had been classified as nebula in earlier days, proved to be vast stellar systems, not unlik our own Milky Way, but so distant that it had been impossible to see their individual stars. To distinguish them fro true nebulae they are called *galaxies* (from the Gree *galaxias*, milky), but the designations "nebula" and "extragalactic nebula" are still encountered in astronomical literature. Galaxies often exhibit a characteristic spiral shap (see Messier 33, at left, *above*) with enormous arms winding around a bright nucleus of tightly packed stars. Other are more nearly elliptical, or frankly irregular. Thes shapes seem to be directly related to the composition o the galaxies. Very hot stars and associated interstellar ma

f sight, making it hard to ascertain ts form. Galaxy is in Coma Berenices.



DUMBBELL NEBULA, a planetary nebula, represents a gaseous shell illuminated by a very bright central star. About 750 such planetary nebulae are known.

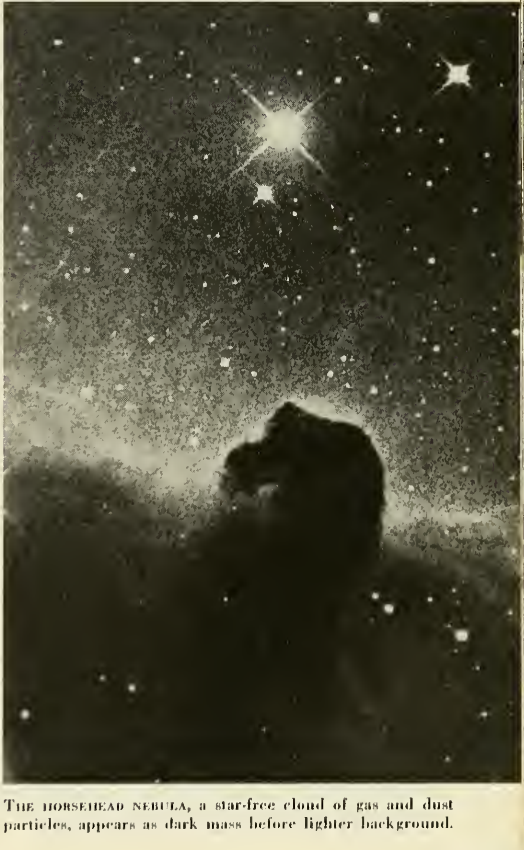
erial are found almost exclusively in spiral arms. Elliptical :alaxies, on the contrary, seem entirely devoid of these eatures. Current theories on the formation of stars hold hat extremely hot ones may be very young; if this is correct. spiral arms may be a sign of youth.

THE greatest difficulty in determining the structure of our own Milky Way galaxy comes from the fact that ve are embedded in it. The problem is akin to being in a trange house and trying to guess the appearance of its acade without being allowed to step outside; one could nly estimate its dimensions. take inventory of its rooms. nd look through a window for a similar house across the treet. Astronomers have done just that for the Milky Way.

The presence of vast amounts of nebulosity and bright oung stars hints at spiral structure. But until a decade ago, : was impossible to substantiate the belief that the Milky Vay is a spiral galaxy except by drawing analogies with ther spirals such as the Great Galaxy in the constellation ndromeda—a near neighbor as astronomical distances go. nd close enough for detailed scrutiny.

The large concentration of stars in the general vicinity f Sagittarius suggested that this might be the direction of ne Milky Way nucleus. and that our sun lies at the perihery of the system. Efforts to observe the nucleus itself ere frustrated by the presence of large amounts of obscurng matter in that direction.

The problem was solved after the introduction of radio lescopes designed to observe the radiation of neutral ydrogen at radio frequencies. Because hydrogen is very bundant in spiral arms, and because its emission in the adio spectrum can penetrate obscuring clouds, it became ossible, a few years ago. to trace the pattern of hydrogen early throughout our entire galaxy. The presence of spiral rms was unmistakable. As further corroboration of the eneral shape of the system, wide-angle photographs taken the direction of Sagittarius show that this region of the lilky Way has a structure strikingly similar to the middle f the edge-on galaxy in the center photograph, *above*.



THE HORSEHEAD NEBULA, a star-free cloud of gas and dust particles, appears as dark mass before lighter background.

THE SKY IN NOVEMBER

From the Almanac:

New Moon	November 8, 4:59 A.M., EST
First Quarter	November 15, 7:13 A.M., EST
Full Moon	November 22, 4:44 A.M., EST
Last Quarter	November 30, 1:19 A.M., EST

For the visual observer:

Mercury, in the morning sky, will reach its greatest western elongation on November 7. Some 19° west of the sun that day, it will rise about an hour and three-quarters before sunrise and it will be found very close to the planet Venus. It will be favorably placed for observation during the first half of November, rising one and a quarter hours before the sun on November 1, one and a half hours before the sun on November 15.

Venus, also a morning star, will rise at approximately 4:45 A.M., local standard time, on November 1, 5:15 A.M. on November 15, and 5:45 A.M. on November 30. It will be low in the southeastern sky shortly before sunrise.

Mars, in the evening sky, will be too close to the sun to be observed conveniently.

Jupiter, in Capricornus (-1.7 magnitude) will be low in the south at sunset. The planet will set in the southwest at approximately 10:15 P.M. on November 1, 9:30 P.M. on November 15, and 8:45 P.M. on November 30.

Saturn ($+0.8$ magnitude) will be in Sagittarius, approximately 5° west of Jupiter and will set about forty-five minutes before that planet.

Two meteor showers may be expected in the course of the month: the Taurids on November 5 and the Leonids on November 16. Both have an estimated maximum of fifteen meteors per hour for a single observer.

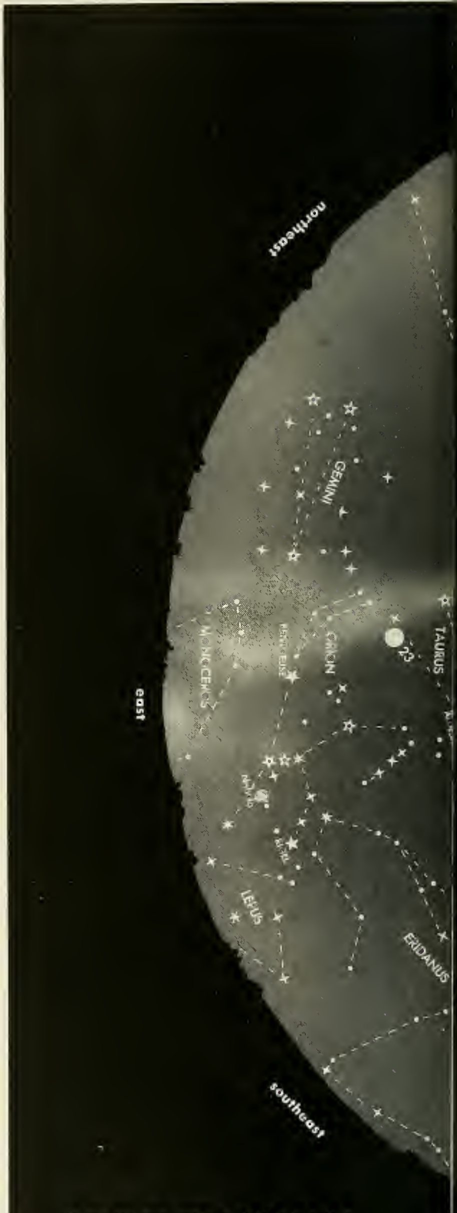
Elongations of Mercury and Venus:

Because Mercury and Venus have smaller orbits than that of the earth, they are never seen very far from the sun. To a terrestrial observer, they seem to oscillate between two extreme positions on either side (east and west) of the sun. Astronomers use the term *elongation* to designate the angular distance in longitude between the sun and a planet; accordingly, the expression "greatest elongation" is applied to these extreme positions.

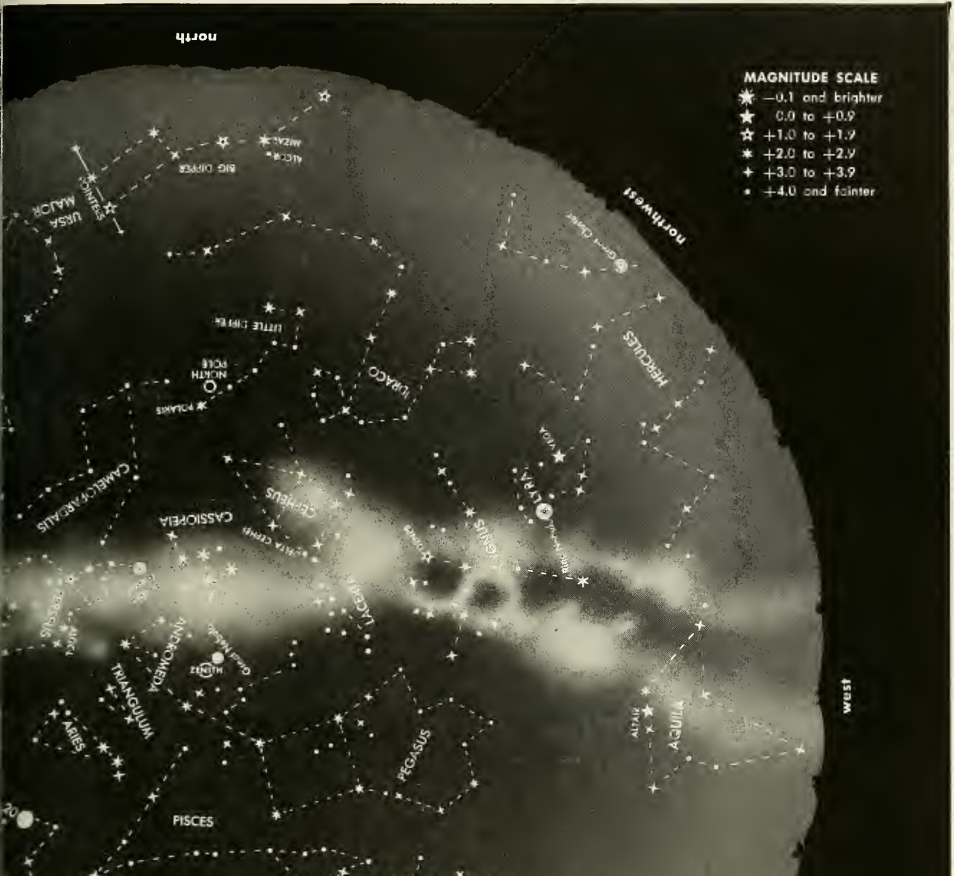
Since planetary orbits are not perfectly circular, successive greatest elongations have a slightly different angular extent, depending on the orbit's orientation in the line of sight. This effect is particularly noticeable for Mercury, whose greatest elongation varies from 18° when the planet is at perihelion (the point in its orbit closest to the sun) to 28° at aphelion (the point in its orbit farthest from the sun). In the case of Venus, the greatest elongation of the planet's orbit has been found never to exceed 48°.

Greatest elongations of Mercury are not all equally favorable for observation. The planet moves very nearly along the great circle of the ecliptic—the apparent path of the sun among the stars—and it is most readily observed when the ecliptic is most tilted to the horizon. At our latitudes, this condition is fulfilled in the spring for the evening sky and in the fall for the morning sky. Observations of Mercury should, therefore, be scheduled accordingly.

On the preceding pages, MRS. GOSSNER offers the ninth in her 1961 series on the growth of cosmological concepts.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.


north
northwest
west
southwest
south
URSA MAJOR
POINTERS
BIG DIPPER
MIZAR
ALCOR
LITTLE DIPPER
NORTH POLE
POLARIS
DRACO
HERCULES
Great Cluster
VEGA
LYRA
CYGNUS
DENEB
CEPHEUS
DELTA CEPHEI
CASSIOPEIA
CAMELOPARDALIS
PERSEUS
ALGOL
LACERTA
ANDROMEDA
Great Nebula
ZENITH
TRIANGULUM
ARIES
PEGASUS
PISCES
ALTAIR
AQUILA
CETUS
AQUARIUS
CAPRICORNUS
JUPITER
FOMALHAUT
SCULPTOR
PISCIS AUSTRINUS
GRUS
20
17
14

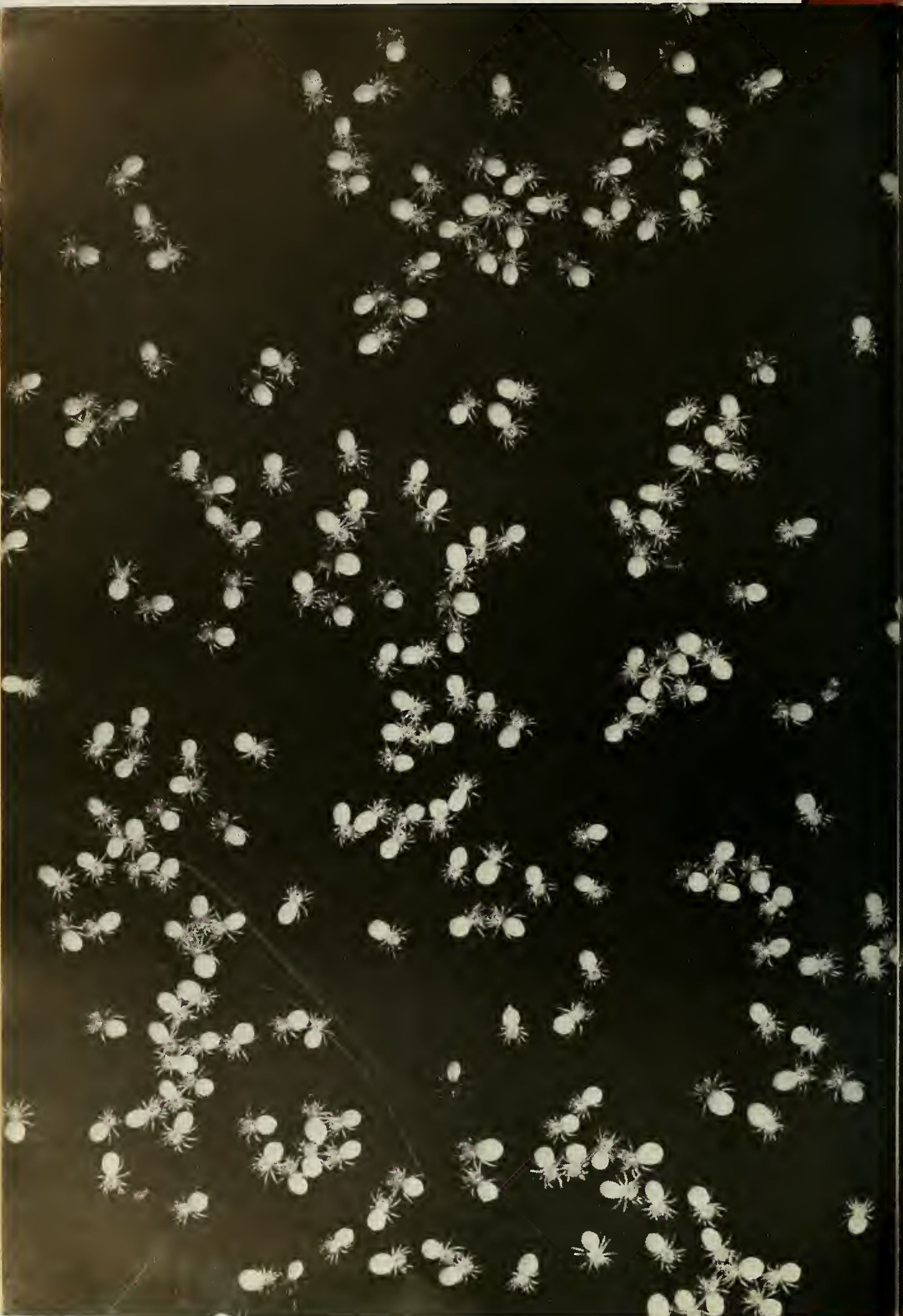
MAGNITUDE SCALE

✷	−0.1 and brighter
★	0.0 to +0.9
☆	+1.0 to +1.9
✶	+2.0 to +2.9
✦	+3.0 to +3.9
•	+4.0 and fainter

TIMETABLE

November 1	10:00 P.M.
November 15	9:00 P.M.
November 30	8:00 P.M.

(Local Standard Time)



The Male Spider

Myth wrongly labels him few in numbers and sorry in prospects

By Theodore Savory

In thousands of homes across the land this fall, a standard scene will be played. A large, long-legged spider will scurry rapidly across the living room floor and disappear under the piano or behind a sofa. A woman will shriek, or nearly, and demand that the man of the house find and kill the lurking creature. The peace of the fireside will remain disturbed until an entirely harmless arachnid has been driven from hiding with umbrella or broomstick, trapped in a tumbler, and flung outdoors or mercilessly committed to the flames.

This is not the place to examine the irrational fear that the luckless animal has aroused by its unexpected arrival. But when calm is restored, it is interesting to observe that almost no one out of the human cast of thousands will have noticed these facts: the season is autumn, the time is evening, and the spider is (or was) a male of the genus *Tegenaria*, one of the fairly common house spiders.

Among the first notions that a student of spiders acquires are these traditional ones: that male spiders are rare, that they do not spin webs, and that they are eaten by their mates. All three notions, as we shall see, are false in whole or in part. Collecting in woods and fields seems to confirm the males' apparent rarity and so, perhaps, excuses belief in the other two notions. Male spiders certainly are peculiar: there cannot be many animals among the invertebrates in which the attainment of maturity is accompanied by so great a change in the behavior of the sex.

What are the outward and visible signs that show a spider to be a male? In nearly all male animals, the testes—the glands that secrete spermatozoa—are directly connected by two ducts called the *vasa deferentia* to an organ that either ejects the sperm into the water over newly laid eggs (as in many fishes), or transfers it to the body of the female. The testes of a male spider occupy a normal position in the abdomen, and the *vasa deferentia* open at an inconspicuous orifice just behind the waist. But the spider's two intromittent organs are nowhere in the neighborhood. They are found, instead, at the ends of the pedipalpi—a pair of leglike limbs arising from the sides of the spider's mouth and in front of its first pair of legs. In female and *young* male spiders, these pedipalpi are tactile organs, freely supplied with sensory hairs. But when the male matures, the last segments completely change their appearance.

This change has already begun at the time the male undergoes its next-to-last casting-off of the skin. Then the palps can be seen to be swelling at their tips. This is due to the maturation of the male organs; they will appear fully developed when the skin is cast for the last time. The palps' last segment, which in its early developmental stages resembles a finger and later looks like a thumb with a single, terminal claw, has now become a hollowed, spoonlike container. The claw has disappeared or has become converted into part of the elaborate apparatus forming the spoon.

So much for the first traditional notion—the apparent rarity of male spiders. During more than three quarters of their lives, males cannot be distinguished at sight from their sisters. Their palps resemble those of the opposite sex and, since there is no difference between male and female activities, one naturally, if unthinkingly, tends to look upon all such immature forms as females. In fact, however, half of these supposed females are unannounced males.

In the past, several authors believed that they had found secondary differences that enabled them to separate the spiders according to their sex as far back as the egg stage, but these secondary signs are now discredited. Investigators who have raised spiders from cocoon to old age have found that the proportions of the two sexes are about equal.

Why, then, are mature male spiders rare? During recent years, I have made it a practice to keep in captivity (and to watch with special care and interest) any sub-adult males of the genus *Tegenaria* that I have been able to find. It was my hope to detect any male change from "female" behavior that might occur at this stage of approaching maturity. The results have been negative. When put into cages, these sub-adult males spin normal webs, eat the flies with which they are supplied, feed with the usual greed if given the opportunity, and in no way support the dictum that coming events cast their shadows. Finally they molt.

At this point, another traditional notion must be revised. It is true that if *mature* males are kept in cages for some time, their webs fall into disrepair; evidently the webs are not receiving the nightly quota of added silk that formerly restored the ravages of the chase. But this is not apparent at once. If an adult male *Tegenaria*, which has just molted for the last time, is put into a new cage, it will spin a web and feed on flies, continuing for perhaps ten days or a fortnight to lead the same old life. Then a moment comes when it takes a first step toward achieving its male function.

The spoonlike palpal organs, which have already been described, are now complete, but they contain no sperm. It is obvious that the palps should now be swung round into contact with the sperm-emitting orifice in the spider's abdomen, and so receive a charge of semen. It is obvious, except for one thing: the palps are too short—the orifice is beyond their reach.

The male spider overcomes this difficulty by spinning a small, special web called a sperm-web), depositing a drop of semen thereon, and then immediately applying the palps to that drop. They take up the fluid as would a syringe. This remarkable pro-

Brood *of newly hatched spiders, left, contains equal numbers of both sexes. Immature males look like females.*

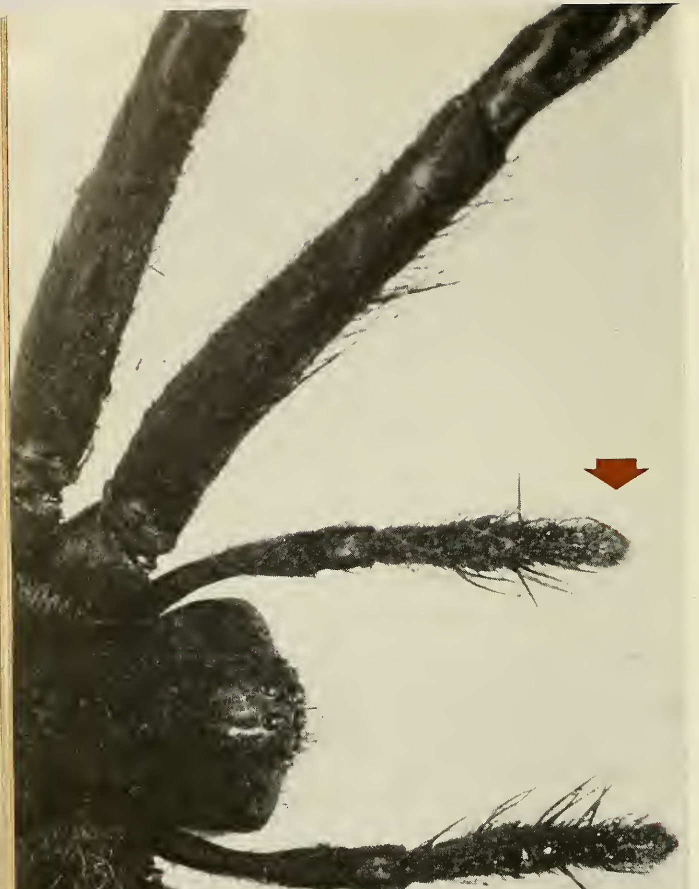
cess, called sperm-induction, was first seen by the German zoologist A. Menge in 1843. The action is carried out by some species of spiders before a female has been discovered; by others it is included as a preliminary to, or an early stage of courtship. By others, again, it is postponed until courtship has been proceeding for some time, or it is hurriedly repeated if unions are numerous or prolonged.

The sperm-web is usually triangular or rectangular in shape and is spun in an inclined or almost vertical plane. When it has been made, the spider shakes or rubs his abdomen upon it, depositing a drop of seminal fluid, and into this drop the palps are inserted, usually in turn but exceptionally together; the fluid is drawn up by surface tension. The whole process takes from five to twenty-five minutes.

With its palpal organs fully charged, the male *Tegenaria* begins a wandering life, in which it seems to be more highly sensitive to environmental detail than before. Perhaps this increased perception is a result of the tumid state of the palps; perhaps hormones are responsible. Driven by whatever stimulus, the male wanders abroad, seeking it knows not what.

How far must our *Tegenaria* go? How far can it go? Calculation will answer the first question, for the average distance to be covered by any male wandering at random can be determined—given, first, the lengths of its legs; secondly, the diameter of the female web with which the legs must come into contact; and thirdly, the population density of the species. To clarify the mechanics of this phenomenon, it should be mentioned that the sense organs on the tips of the males' legs inform them when they have stumbled onto a female's web. And since a spider walks with its legs more or less parallel to the ground, spiders with longer legs cover a greater area as they move. Likewise, a larger web is more apt to be chanced upon than is a smaller one. (The situation is like that of ice floes drifting on the Arctic Sea: their areas affect their chances of touching one another.) The whole matter is further complicated by the fact that, among some species, both sexes are wanderers, while among others only the male wanders, in search of the female's web.

The *Tegenaria*, with which we are concerned, belongs to the second of



Pedipalpi of a mature female spider—here magnified considerably—resemble a young male's, but sole function is as tactile organ, aided by sensory hairs.

these categories, and the distance a male of this type of spider would have to walk before first meeting a female's web is expressed by this formula:

$$\text{Average Distance} = \frac{a}{(d + s) \times n}$$

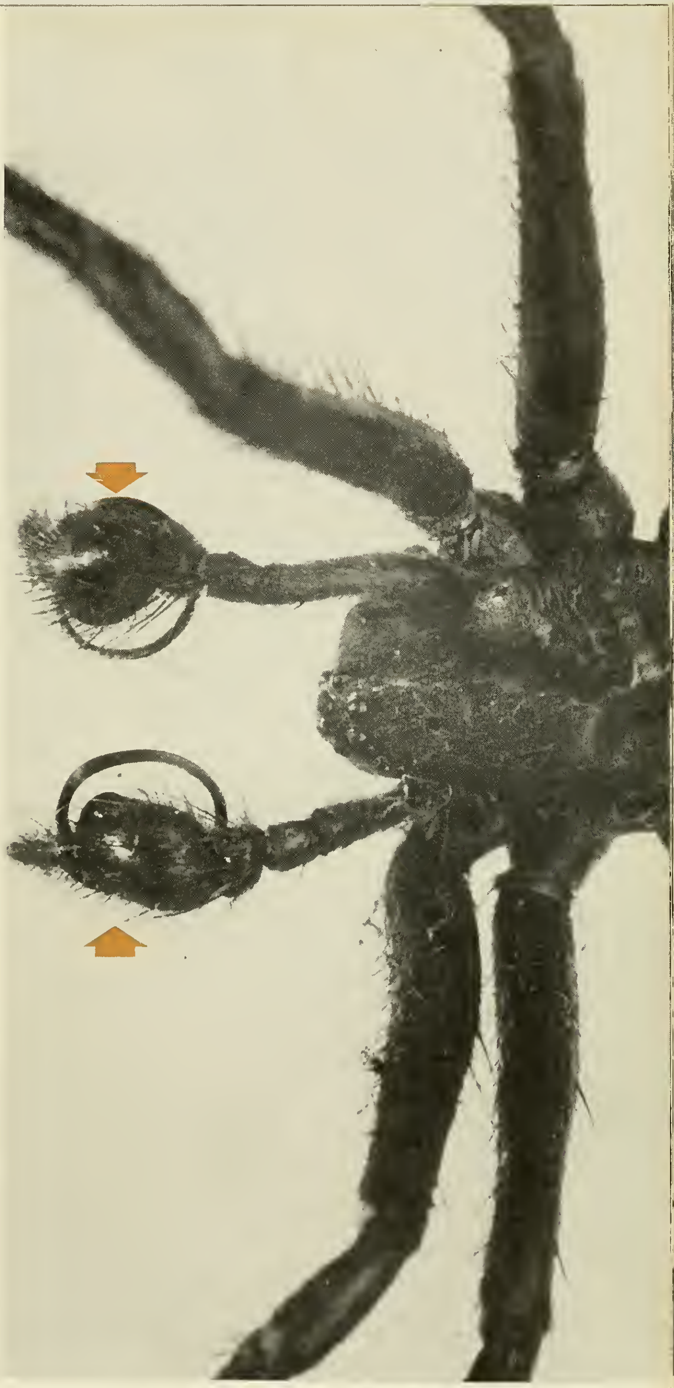
Without getting involved here in the mathematics by which such a formula for random wandering is arrived at, we may apply this one by substituting the area of the spiders' immediate habitat for "a," while "d" is equal to the diameter of the female's web, "s" is equal to the over-all spread of the male's legs, and "n" equals the number of webs of the particular species' females in the given area.

If it is assumed that the male has legs one inch long, giving a span of two inches from side to side, that the female's web has a diameter of twelve inches, and that there is one such web in a cellar that measures 21 feet by 15 feet, then the male spider may expect to have to walk 90 yards before coming upon a web. If there are two webs, he walks only half the distance; if three webs, then he walks one-third the distance, and so on.

To these cold figures must be added the information that the number of spiders of all species per acre is not likely to be one or even a hundred, but may reach a total of more than two million. Even if only a small proportion of this population can satisfy the needs of one wanderer, it seems unlikely that any male spider runs much risk of bachelorhood.

How far the male *can* go is, in my opinion, more important than how far he must go. Even if a male spider has to walk only fifty yards, it is likely to be wearied by the effort. It is a member of a sedentary, not a vagrant, species; the thoracic muscles, which have to move its eight long legs, are very small. Data on this question, however, are lacking. We know only that the wanderer never rests, but perseveres until the sense organs of the foot report it is treading on the web of its future mate.

Immediately the male's behavior changes. Now begins a series of sometimes prolonged preliminaries, which delay the transfer of the sperm. These actions have been fully described for very many different species under the unfortunately anthropomorphic name of "courtship." A few remarks on spider courtship are therefore pertinent.



LAST SEGMENT of mature male spider's pedipalp has developed through series of stages into spoonlike organ that is used to transfer semen to the female.

Mr. Savory, the Vice-Principal of Stafford House College in London, is the author of books on philology as well as on spiders. He is making his first appearance in this magazine.

First, we need intensive study of the courtship patterns of single species, so individual variations can be eliminated and the really essential details retained. It is among such species-predictable details that the most effective stimuli and appropriate responses will be found.

Again, we must know the effects on courtship of the conditions of the spiders themselves. We need comparisons between a recently molted male and one that has been mature a week or more before being allowed upon a female's web. Similarly, we require comparisons between the reactions and receptions of recently matured and long-matured females. We must contrast hungry with well-fed spiders of either sex. This has not yet been done in sufficient detail.

Third, in all published descriptions of spiders' courtship it is the male that steals the limelight. We are told of everything the male does: yet the female is also receiving stimuli, and it is unlikely that she does not react at all. A little attention directed toward the female partner in these rites might be well rewarded.

Traditionally, accounts of courtship in spiders have been badly distorted by the myth that the female will inevitably kill and eat the male, and that the ritual of courtship is designed to prevent this. It is seldom pointed out that there are species of flies where the male, like the spider, will pay court by posturing and leg-waving in front of the female: or that the male of at least one species of fly offers a morsel of food to the female, as does the more widely known spider *Pisaura*. Such flies are carnivorous, but not so cannibalistic that the male needs this protection. The "insurance-policy" theory of courtship, in my view, is no more valid for explaining spiders' behavior than it is for explaining flies' behavior.

One of my most revealing glimpses of the living spider in nature was given me one afternoon in the fields of Herefordshire, when I saw a male *Lycosa lugubris* walking across the trunk of a fallen tree. It was the only spider in sight at the moment, but suddenly it stopped and, without apparent reason, began its courtship actions. It continued to raise and lower its palps for perhaps half a minute, and very absurd it looked, all alone on the broad expanse of wood, energetically courting nothing. Perhaps this instance supports the hypothesis of the occurrence of what Konrad Lorenz has called "vacuum activity." The internal drive or urge may have reached such intensity that a set of reactions, which would normally appear as courtship movements only when the correct stimulus was present, broke through the male's neuromuscular controls and took place in the female's absence. It was an abnormal but illuminating event.

From it, we could go on to build up a picture of the male spider, under compulsion from internal stimuli, responding to a combination of external stimuli that leads to its peculiar pattern of courtship. This would bring the spiders' courtship into line with observations and conclusions on other kinds of behavior seen among animals of many different kinds. In this connection, it is reasonable to suppose that a special combination of stimuli is necessary to induce an act that characterizes the species and which may be performed only once in a lifetime. But it is far less reasonable to picture the courting male as precariously poised in an anthropomorphic fashion, torn between desire and fear. Actually, he has been driven (or guided) by the inexorable accident of statistical probability into a situation toward which his whole existence has been directed, and in which the nubile female is to be the essential stimulus.

For *Tegenaria*, courtship is a relatively simple process. The male drums on the web with its pedipalpi in a very characteristic way; the vibrations thus set up reach the female, for whom they possess a very different significance from that of the vibrations of a fly in these same meshes. The female does not rush out to the kill; instead, the male, drumming unceasingly, slowly approaches the female.

An aspect of the male spider's behavior that has not hitherto been sufficiently stressed is this: the search, the courtship, and the mating have been three successive and increasingly strenuous activities. Sometimes the search has been so tiring that the courtship is imperfectly performed; sometimes the courtship is so strenuous that the male cannot finish it; finally, there is at least one case on record in which the wearied male died during mating. Hence the third of our traditional notions.

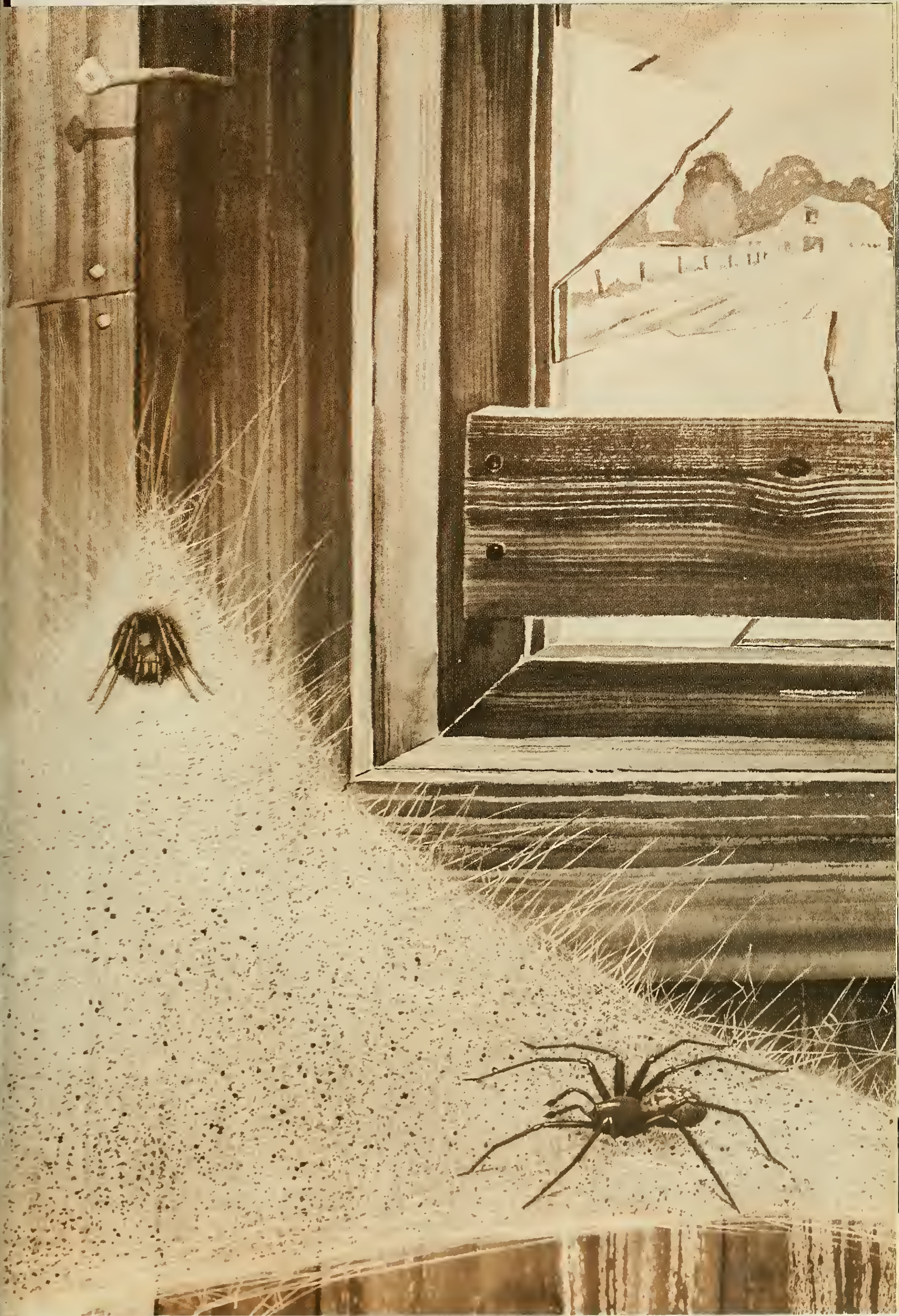
Even when it does not die, the fulfilment of its function in continuing the species leaves the male spider without purpose. Biologically, no great extension of its life can be justified: in fact, it is clear that the animal is exhausted—"run out," as the gamekeeper says of his stags. At the end of their rut, however, the stags at least can rest, feed, and regain strength: male spiders cannot. With the coming of maturity, they have forsaken their webs to go a-wooing, sacrificed their chances of ever catching another fly, and condemned themselves to starvation.

My observations carry the story further: on the basis of these, I believe that male spiders are *never* very robust. Far from being full of the virility that the stories of their dances suggest, far from showing an enhanced activity from "the greater metabolism of the male" mentioned in textbooks, the males are weaklings, clinging to lives that seem to have one object.

In September, 1953, I had a mature male *Tegenaria*, apparently in the best of health, living in a box in a good web of its own making. I put a vigorous fly into the box as a meal for the spider, but the insect was too strong to be entrapped by the web. Time and again, the spider rushed out to the source of disturbance of the silk, but always the fly escaped and the spider returned to its resting place. A few hours of this were more than the spider could support. The shaking of its web gave it no rest; it was compelled to run out to the stimulus again and again until, completely exhausted, it died.

We can conclude, then, that the death of the male spider is due to its constitutional weakness and not, as is usually thought, to its mate's cannibalism. But if, as we have seen, the male does not correspond to the traditional image we have of it, investigation has not made this animal much less puzzling. It has, instead, hinted to us what the actual puzzles may be.

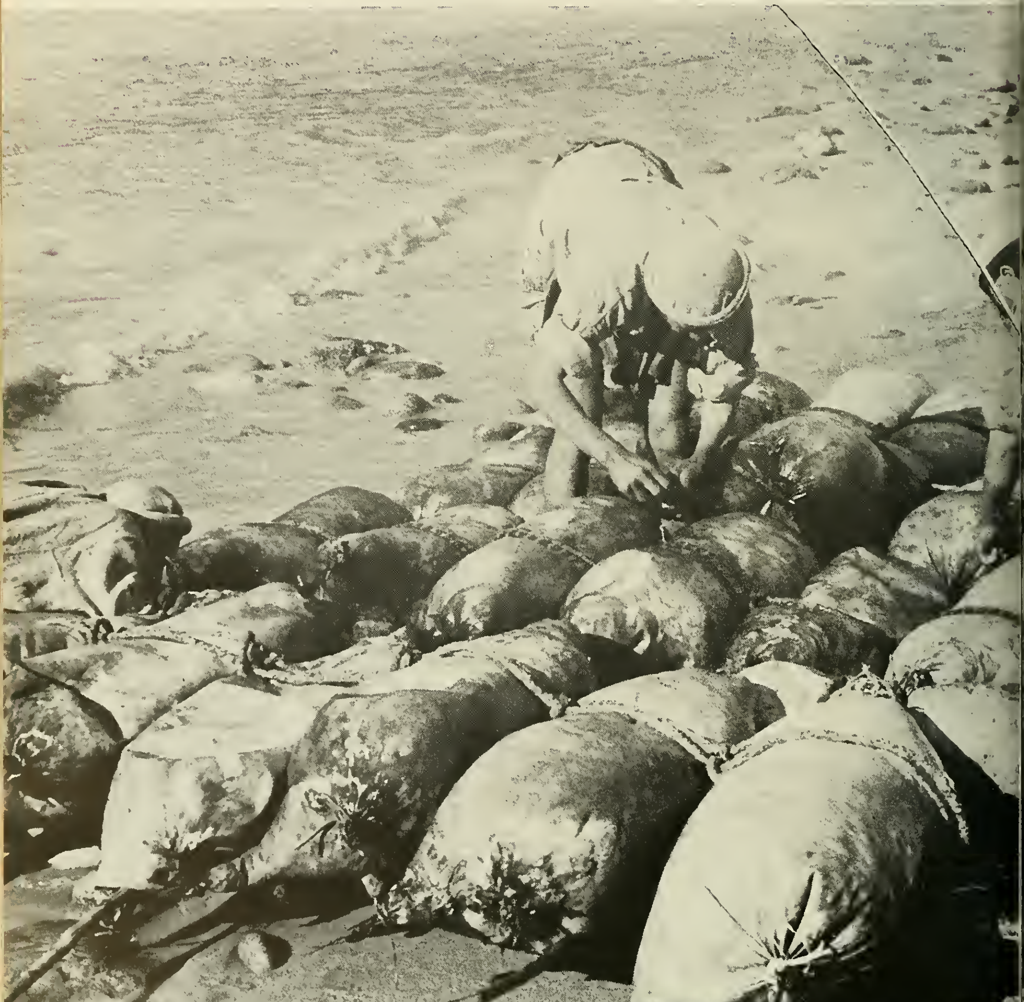
Climax in male's life comes as, palps charged, he comes upon female's web, begins to vibrate it in distinctive way that signals preliminaries of courtship.



Part II

People of Baltistan

Agriculture, herding, and dairy farming form the basis of



Air sacks of a skin raft are tightened and reinflated after trip down Shigar River in Baltistan. Normally used in calm water, the rafts can ride rapids.

By

JAMES HURLEY

he Balti economy

Rope bridge casts a shadow on Braldu River as Balti porters cross. Bridge is made of interwoven branches, with a stick at mid-span to spread handrails.

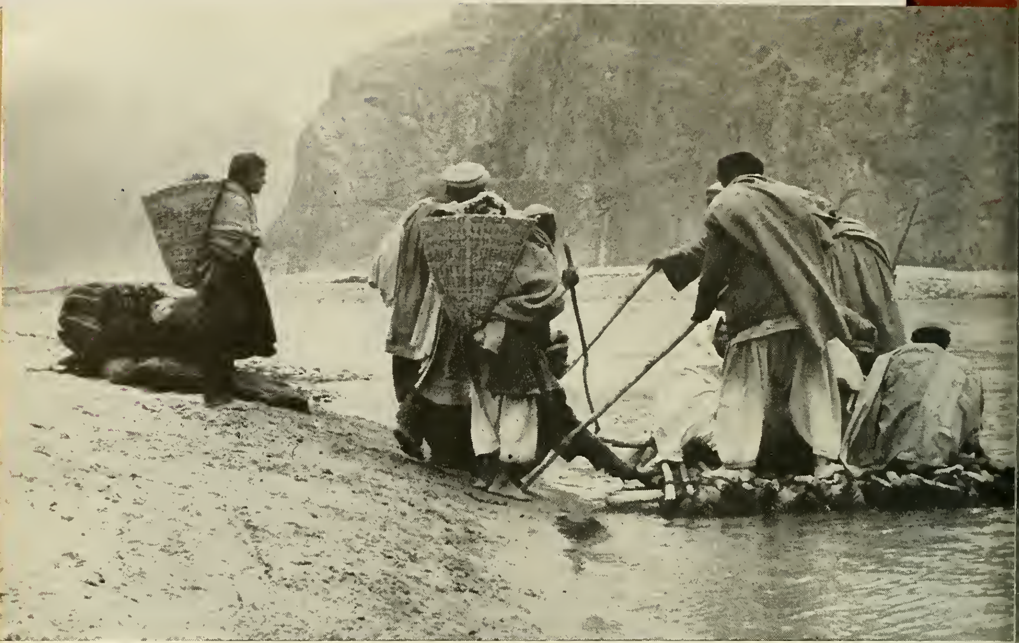
During the two centuries that the British stayed in India, they penetrated into nearly every corner of the country and found out almost all there was to know about it. This was not only because of British administrative and security needs, but also because of a national penchant for adventure—combined, in many cases, with a taste for scholarly endeavor and interest in the culture. Thus was produced a wealth of factual and descriptive books that will long remain a monument to British rule in India. The "District Gazetteers," in particular, are exemplary, for they relate in minute detail all that was known at the time about the people of a given district—their history, ethnology, language, folklore, and economy.

But for Baltistan there were no "District Gazetteers," since the country was both distant and under another administration, that of the Maharaja of Kashmir. The British did not extend their rule into north India until the middle of the nineteenth century, and for various reasons, including administrative expedience, they left Kashmir and its several far-flung districts in the hands of a Hindu soldier-prince. Although British officials were stationed in Kashmir during the next hundred years, there were few of them, and they generally served as "advisers." Their numbers grew, however, during times of military or political tension.

Because Kashmir occupied a strategic position at India's juncture with China, Russia, and Tibet, and because the maintenance of cordial relations with the ruling prince was important to the regime at Delhi, it was necessary to obtain permits to visit the area. This was only a formality in the case of Srinagar and the Kashmir Valley, but it took on real meaning as applied to such frontier areas as Baltistan and Ladakh. However, when it became known that the hunting was excellent and that prize ibex heads were to be had in the faraway Karakorams, red tape disappeared in the face of attacks from that formidable breed known as "the British sportsman." And so the region was "discovered."

In the latter nineteenth century, Sir Francis Younghusband's daring trip from Peking across the Gobi Desert and into India over the Muztagh Pass excited world interest in the Karakorams. Soon after that, the great scientific and mountaineering expeditions began to arrive. The first, in 1892, was mainly British, led by Sir William Conway. The expedition penetrated to the Baltoro Glacier, one of the longest glaciers in the world outside of polar regions. The members mapped much of the tributary glacier system and climbed several peaks.

Between 1899 and 1912, Mrs. Fanny Bullock Workman, an American, and her husband, Dr. William Hunter Workman, conducted five expeditions to Baltistan and the Karakorams. Other major scientific and mountaineering expeditions in the early years of this century were those of the Duke of the Abruzzi, 1907-08, and of an-



BOATMEN PREPARE to ferry passengers across Shyok River at Khapalu. Conic grass baskets on villagers' backs are made in accord with the size of user.

other Italian, Dr. Filippo de Filippi, in 1913-14. The territory covered by both expeditions overlapped the Karakorams (i.e., Baltistan) and Chinese Turkestan. In 1923-24, the Americans Katherine and Robert LeMoyne Barrett spent a year trekking and climbing in Baltistan and Ladakh. Since then, and particularly in the last ten years, the Karakorams have become an international mountaineering playground. Each year from two to four expeditions contend for the honor of reaching the tops of perhaps a score of unclimbed peaks over 20,000 feet. Americans have had a good share in the conquests of some of them, including Hidden Peak and Masherbrum, and have acquitted themselves well on the 28,250-foot K-2, the second highest mountain in the world, after Evere

What is Baltistan like and how do one reach it? These questions a asked even in Pakistan, for few Pak stanis have had the opportunity perhaps desire to go there. The usu tendency is to confuse Baltistan wi Baluchistan, one of Pakistan's pro inces to the southwest. Yet the area within ninety minutes' flying ti from Rawalpindi, Pakistan's capit

The plane ride (the alternative is twenty-day mule track over the hi and forbidding Deosai Plateau) is citing enough to thrill the most soph ticated traveler. The plane skims ju above successively rising ranges a peaks, and skirts the northwestern si of sprawling, snow- and ice-capp Nanga Parbat, called the "Germa killer" for the twenty-six Germa and porters killed on it in the 1930 Shortly before arriving at Skardu, t plane sweeps into the Indus Gor whose walls often seem to hem it in three sides. Skimming close above last, high buttress, the plane lands Skardu's baked mud field.

Skardu is the administrative a trading center of Baltistan, and it here that one finds the greatest div sity of races and tongues. In t bazaar, Uigur-speaking Turkis fro Kashgar, Pushtoons from Peshaw

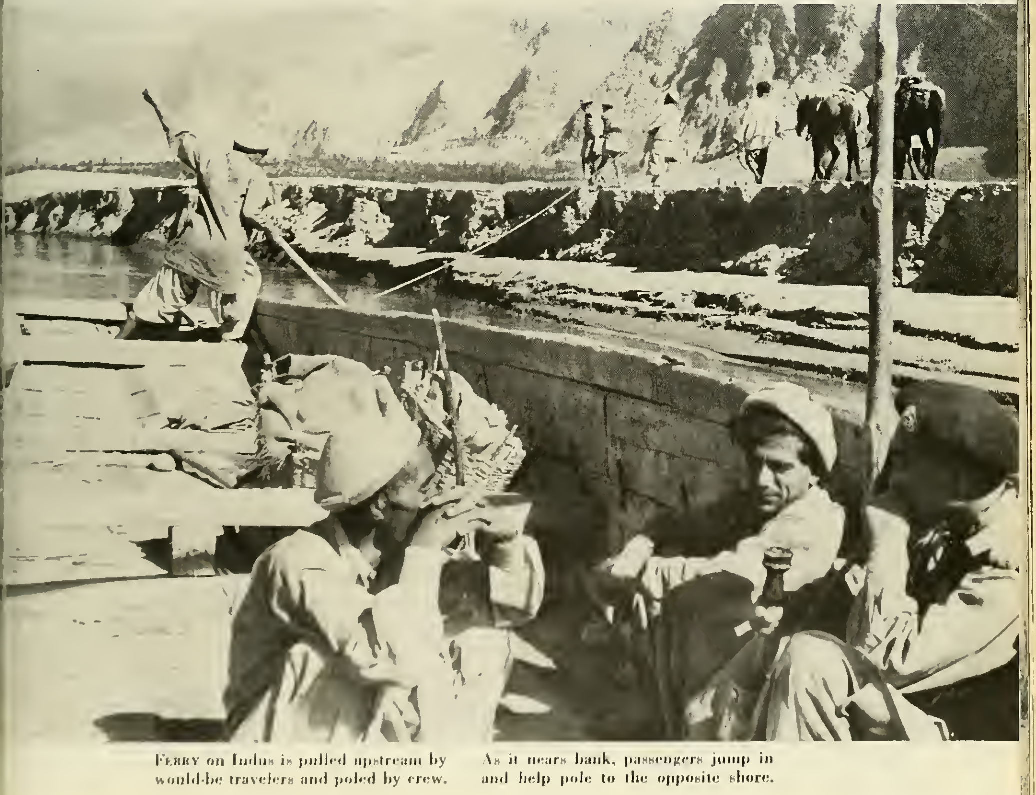
SHOOTING RAPIDS of upper Shigar on a skin raft gave author some anxious moments. Air bladders may be refilled by boatmen while the raft is in motion.

rdu-speaking Punjabis from Lahore, id an occasional Kashmiri vie for the w rupees to be made from a Balti st in from the mountain highland ith a back-load of wheat, butter, or ricots. The Balti sells his goods for lt and tea, and perhaps—if his wife is been persuasive—a bit of bright oth for her. In the *serai*, oddly atad Gujars speaking strange Pahari alects unpack horseloads of chunk lt and kerosene tins brought in carans across the high Deosai route. ie trip may take a heavy toll of their imals if they are caught in a snoworm or one of the deadly cold winds r which the plateau is noted. The rce and nature of these winds can imagined from the occasional blasts at sweep into the Skardu Valley, sually accompanied by lowering rk clouds, they shake houses and ees so violently and make such a ise that one begins to think the end the world will be similar.

In numerous small tea shops one hears some of the dialects and tongues that illustrate the different streams of humanity now comprising Skardu's population: Burushaski from Hunza, Shina from Gilgit, Khowar from Chitral, and sometimes Sindhi or Bengali.

THIS linguistic mélange has affected the local language, and pure Balti is hardly spoken in Skardu anymore. The local patois is such a mixture of Urdu, Balti, Hindi, and Persian that the Balti from other villages say it is hardly understandable. For trading and administrative purposes, Urdu (one of the official languages of Pakistan) is the lingua franca.

The populated part of Baltistan, which lies on the southern and western flanks of the Great Karakoram chain, is made up of a number of valleys. The first of these valleys is that of the great Indus River, running northwest from its source in Tibet, and the rest are those of tributary rivers, such as the Shyok and Shigar, and a number of lesser, glacier-fed streams—the Hushe, Thalle, Braldu, and Basha. From at least the time of the Moslem conversion, local rulers have presided over seven of these valleys or valley sections: Skardu, Khapalu, Shigar, Rondu, Kires, Kharmang, and Tolti. From time to time, other principalities have risen but have usually been short-lived. As far back as is known, these local rulers—called variously *rgyalpo*, *thum*, sultan and raja—have been fighting among themselves. Only in a few instances has a leader arisen influential enough to unite them all—Ali Sher Khan Anchan of Skardu and Ali Mir of Khapalu (and these two are possibly the same person) are the main ones. But generally the raja of Skardu has enjoyed a traditional position of pre-eminence, perhaps because Skardu has always been, as far as we know, Baltistan's trade center.



FERRY on Indus is pulled upstream by would-be travelers and poled by crew.

As it nears bank, passengers jump in and help pole to the opposite shore.

Ibex horns surmounting Balti house indicate that hunter lives there. Ibex figures are often found carved on rocks.

Man of Skardu tamps down a corner of the new earth ro on his house. The typical roof structure of a Balti hon

With the return of the Hindus to Kashmir in 1847, local rajas were stripped of forts and military power and reduced to the status of *jagirdars* (estate holders). To keep them peaceful and reasonably content, they were given privileges such as subsidies, tax exemptions, and rights of revenue collection according to their former importance, degree of resistance—or help—to the invading forces, as well as their current behavior.

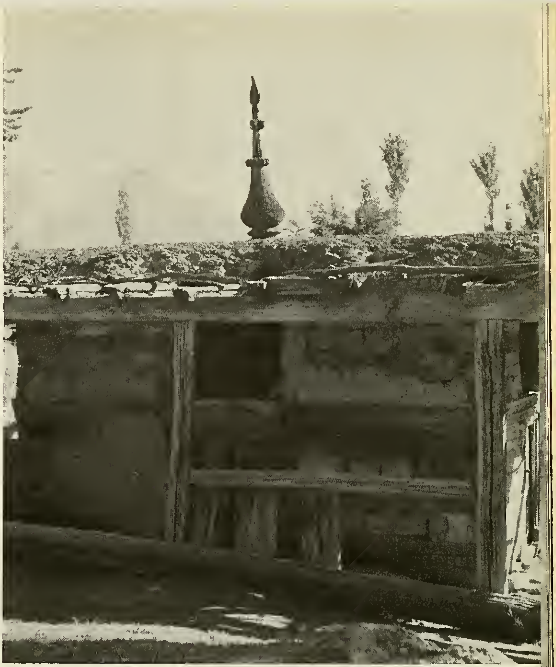
The traditional class structure of the Balti, still observed in name but divested of most of its earlier importance, had, at the top, a raja (*cho*) class, followed by a wazir (minister) class. Membership in the latter carried varying status, depending upon the number of wazirs a particular raja had in his retinue. After these came the *kacho* group, or relatives of the raja. Included in this category were children born to a raja's "ordinary Balti" wives or concubines, who came from non-raja families. Such children were not eligible for succession to the rajaship. Next came the *pahcho* (or "milk-mother") families, whose mothers had suckled a young raja (this practice continues today). At the bottom of society stood the *mon*, a caste of musicians. Another group holding some special status was the *facho*—members of families who had come to Baltistan in the retinue of a future rani (wife of a raja) from the ruling families of the adjacent states of Hunza or Nagar. And yet another was the *bumerak-pa*—those who had accompanied a future rani from the ruling family of Ladakh. Membership in these groups was hereditary, although the wazir class tended to be somewhat transitory, the post originally having been appointive and therefore subject to the political whims of the raja.

The climate of Baltistan is extremely arid—less than six inches of rainfall a year. Since the economy is mainly agricultural, irrigation poses a considerable problem. Despite the fact that running water is the most characteristic sound in Baltistan, the problem of how to raise water to the flat, cultivable spots that often lie hundreds of feet above glacial torrents is a knotty one. The Balti solution has been to construct rather amazing complexes of take-off canals, aqueducts, channels, ditches, and rivulets, which they direct with consummate skill through innumerable layers of neat terraces. The water flow is controlled by mutual consent, each group of fields being allocated a certain day time during which the water flows.

During the British period, the Ba were famed in India as road-builde This was probably in part the resu of practice they had building take- channels. The channels are often mo than a mile long and sometimes ha to be built across precipitous ro faces and perilous avalanche slope Many a Balti has been killed whi building one. Sometimes the wat flow is carried in hollowed lo perched on wooden stilts or timbe jammed into a crack, but more oft they run on elaborate masonry fou dations built out gradually from t wall below. The longest one. Skardu, constructed of massive gra ite blocks, stretches some three mil and in its last reaches consists of canal raised some fifteen to twen feet above ground level. Tradition h it that it was built by order of the la Buddhist Queen of Skardu, Mend Gyalmo, about five centuries ago. N one knows how the blocks were move

A typical Balti village can be d scribed best as an oasis. To apprecia this, it is necessary to contrast villa sites with valleys. The valleys are i variably barren and formidable, wi rock and shale escarpments sweepi

etwork of poplar branches supporting layer of packed h. In winter, livestock join the Balti inside houses.



Wooden shrine, *astana,* marks grave of a holy man. Style of architecture may be a carry-over from Buddhist period.

n from rugged, unweathered rock ks beyond which lie others even re rugged or icy. The sharpness h characterizes the peaks may be tributed to the relatively recent geo- gical uplift of the area's mountains, ich are classified as at least as "new" he Cretaceous period. The starkness the long-uninhabited sections of h valleys, surrounded by imposing pes, can be oppressive: to come upon of the small splashes of green that ks a village is thus always a pleas- t. Invariably, villages are nestled at bottom of some glacial stream rsing from the mountain behind m. Tall poplar trees, a wooden- pled mosque in the center; and ged children playing in the green s are the most characteristic fea- s of a village scene in Baltistan.

Most of the villages exist on a subsistence level. Little trading irs between them. When the crops harvested and the villagers go n to the nearest big center to pay r land revenue, they may take e extra grain to exchange for salt, and perhaps a few luxuries such matches and tobacco. Their princi- pal crops are barley, wheat, and mil- t while potatoes, spinach, turnips, carrots, radishes, peas, beans, and a few other vegetables are also grown. In the lower valleys, apricots, grapes, melons, mulberries, and, in a few places, even apples and pears are cultivated. There are more than a dozen different types of apricots and they constitute one of the most important staple products of the Balti: not only do the Balti dry them and subsist through the winter on them, but they also crush the kernels to obtain cooking, hair, and lamp oil. At one time apricots were exported, but no longer. Most areas of Baltistan produce two crops a year. In a few places, three crops are possible. But in high valleys, such as Hushe, Saltoro, and Askole, the season is long enough for only one.

Herding and dairy farming are also important aspects of Balti village life. A man's wealth is judged primarily by the number of his livestock. He who owns more than fifty head of mixed goats and sheep and as many as half a dozen *zhos*, or yaks, is considered extremely well off. The *zho*—particularly adapted to Balti conditions—is a cross between the yak and the cow. The yak is unable to withstand the summer heat of the valleys, whereas the ordinary cow cannot tolerate the altitude of the upland pastures. The *zho* has a high milk yield. Since there are usually no grazing grounds near the villages, all livestock must be brought to upland meadows called *broks*. In late April, as soon as the snow begins to melt, village men and boys start moving the stock, often following the receding snow line to as high as 14,000 feet. Later, the women and girls take over while the men descend to tend the crops. Periodic trips are made to the village in summer to bring down a little ghee and curd, the bulk of which is stored in skins for consumption during the winter.

During the winter, the sheep, *zhos*, and other livestock move in with the family—usually on the underground floor of the house—and man and beast apparently keep warm together. The livestock are fed mulberry leaves, lucerne, barley straw, and dried turnips during this period.

Communication between villages and hamlets is often difficult, depend-

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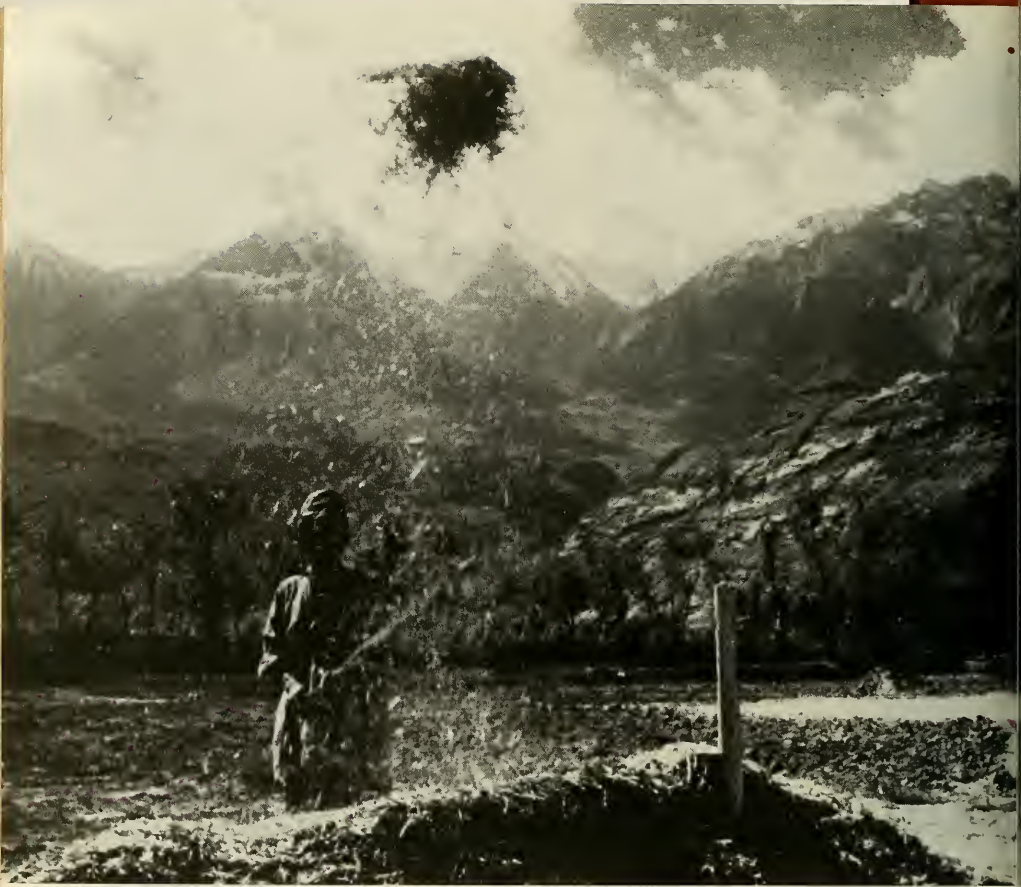
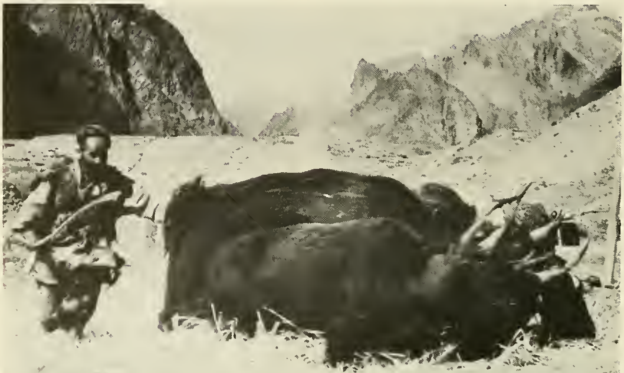
Mr. Hurley, who concludes here his article on Baltistan and its people, made the photographs on these pages during his five trips to the region. Mr. Read's account of Balti village life stems from over ten years' work there with the Central Asian Mission.



Tossing grain in air, a Balti farmer winnows crop in Shigar Valley. Breeze separates chaff from the kernels of grain by blowing it away to the side.



Driven in circle, *zhos* thresh grain in the Hushe Valley, an area noted in Baltistan for its wheat. The *zho* is a cross between the yak and common cow.

ing on the season. In summer, wh glaciers melt, it is virtually impossi to cross the raging torrents that little more than gentle mount streams at other times of the ye Various types of bridges have be constructed by the Balti to overco this. One of them is the rope brid Made of woven branches, it is u mainly to span the larger rivers. cluding the Indus. Crossing one the first time is an experience not so forgotten. The trickiest part occurs the middle of the bridge, where must climb over or under a stick ho ing apart the two handrails: the cho poses a dilemma since the height of stick makes either move awkward.

In the valleys that have sizable p ennial streams, crude but sturdy woo en bridges on the cantilever princi have been built at important crossin They consist of one arch, whose s

porting timbers project over other imbers leading from the bank. The hore ends are weighted with masonry. Where the valley widens and the reshet divides into small channels, ocal villagers merely bridge them with crudely hewn planks or logs. To my mind, crossing these is a harrowing experience, for some are twenty o twenty-five feet long and have a most unpleasant tendency to limberness in the middle. The combination of up and down motion with the illusion of sideward movement from looking t the rushing water is unsettling.

Probably the most enjoyable mode of travel in Baltistan is by *zak* (raft), stick frame lashed onto two dozen or more inflated goatskins. *Zaks* are used

BALTI REAPS GRAIN near Kharmang, in ndus Valley. Surplus may be bartered.

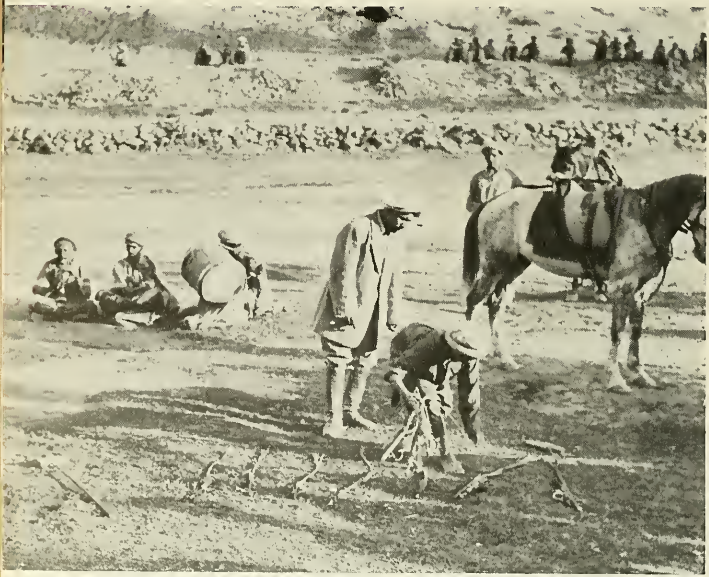
only on the larger rivers, such as the Indus, Shyok, and Shigar, where there are sizable stretches of relatively calm water. But in the hands of four expert polemen these craft can negotiate even foaming rapids.

The only other means of travel in Baltistan are feet—human and equine, the former being the most common. It is not unusual to see dozens of men plodding barefoot into Skardu with loads of more than 100 pounds on their backs, having come as far as 80 to 90 miles. The postal system provides another graphic example of foot travel. Each runner carries the mail for a four-mile stretch—the *dak*, by which the Balti also measure distance. They may be seen day and night, scurrying along valley tracks, their odd, characteristic, fast shuffle-step eating up one *dak* in about an hour. Occasionally, a horse is available for transport, but there are few valleys into which safe pony tracks have yet penetrated. On the whole, horses in Baltistan are more for prestige than for travel but, above all, are for polo.

POLO is the national game of Baltistan and the Balti claim it was theirs first. The Balti word for ball is *polo*, and the Chinese used to call the Balti *Po-liu* or *Po-lu-lo*. The Gilgitis still call them *Paloyu*. Is this mere coincidence or does it indicate that the Balti claim of inventing the game has validity? No one seems to know. This is one more of the many questions about this remote, little-known country that awaits systematic study by ethnologist, archeologist, and historian.

BECAUSE a casual visitor to Baltistan cannot hope to present a detailed account of a typical day in the life of a villager I have asked Rev. Alfred F. C. Read, an authority on Baltistan, to provide the following description. Mr. Read, author of *Balti Grammar*, acquired an intimate knowledge of Baltistan during more than a decade as a missionary there.

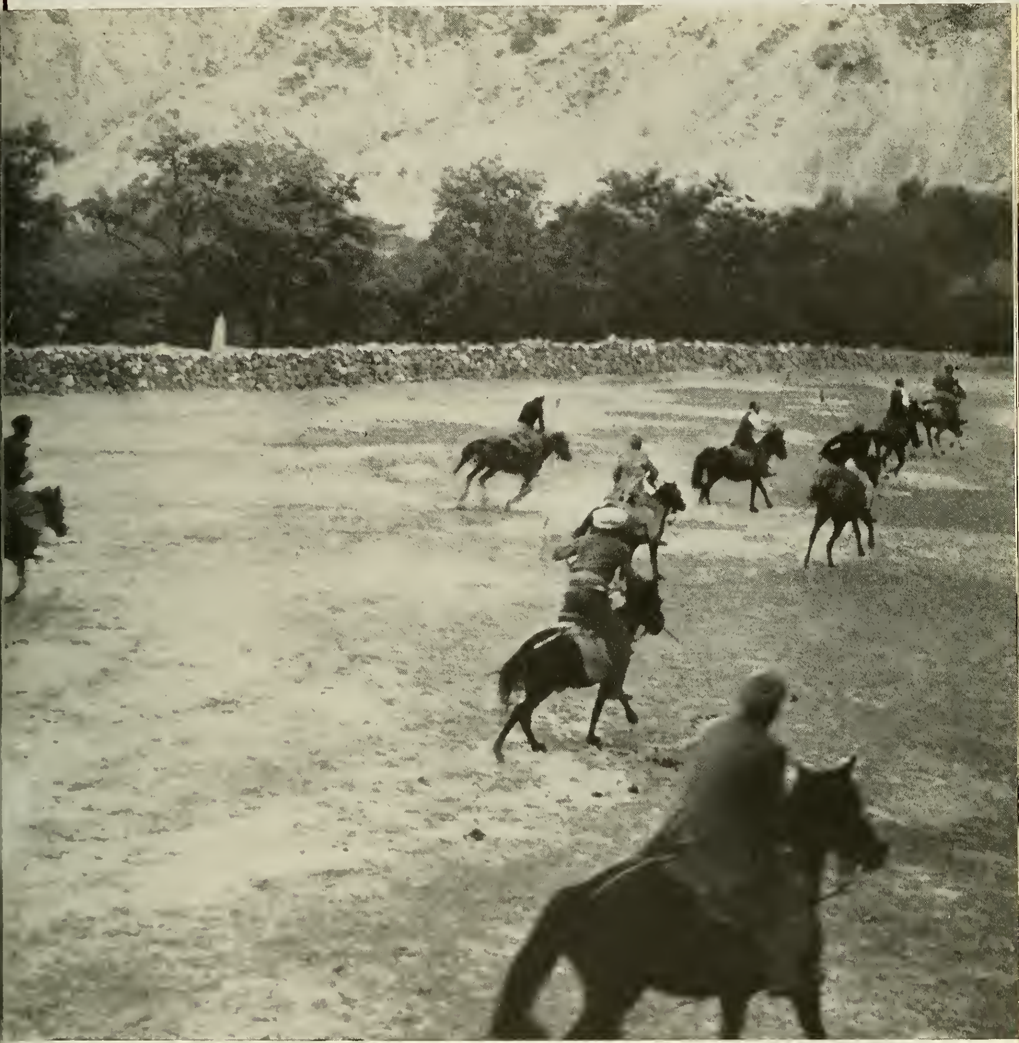
"Shortly before the morning star of autumn begins to dim and the black sky pales slightly, a wooden door creaks on its pivots—it has no hinges—as a Balti leaves his house. He goes to the little village stream to wash, then crosses the dusty field and enters the verandah of the miniature mosque, where he has the task of calling the faithful to the dawn prayer. As his cry in uncertain Arabic echoes along the narrow valley, it seems to stimulate a score of cocks to crow.



POLO TEAM CAPTAIN picks players by selecting half the riding crops lying on the field at Khapalu. Band at left plays during pre-match preliminaries.

"The folk of this valley are Islami
Abdul Kareem is their akhoond l
common consent rather than by ordi
ation. He spent a year or two at t
local primary school but his attai
ments are mainly the ability to de
pher and intone correctly the vers
of the Arabic Koran. For some yea
now he has had the privilege of lea
ership in the tiny hamlet of six hous
of various shapes, sizes, and stat
of disrepair. He performs marriag
prays over the dead, and recites t
Kelima into the ears of the newbo

"By the time the sun lights t

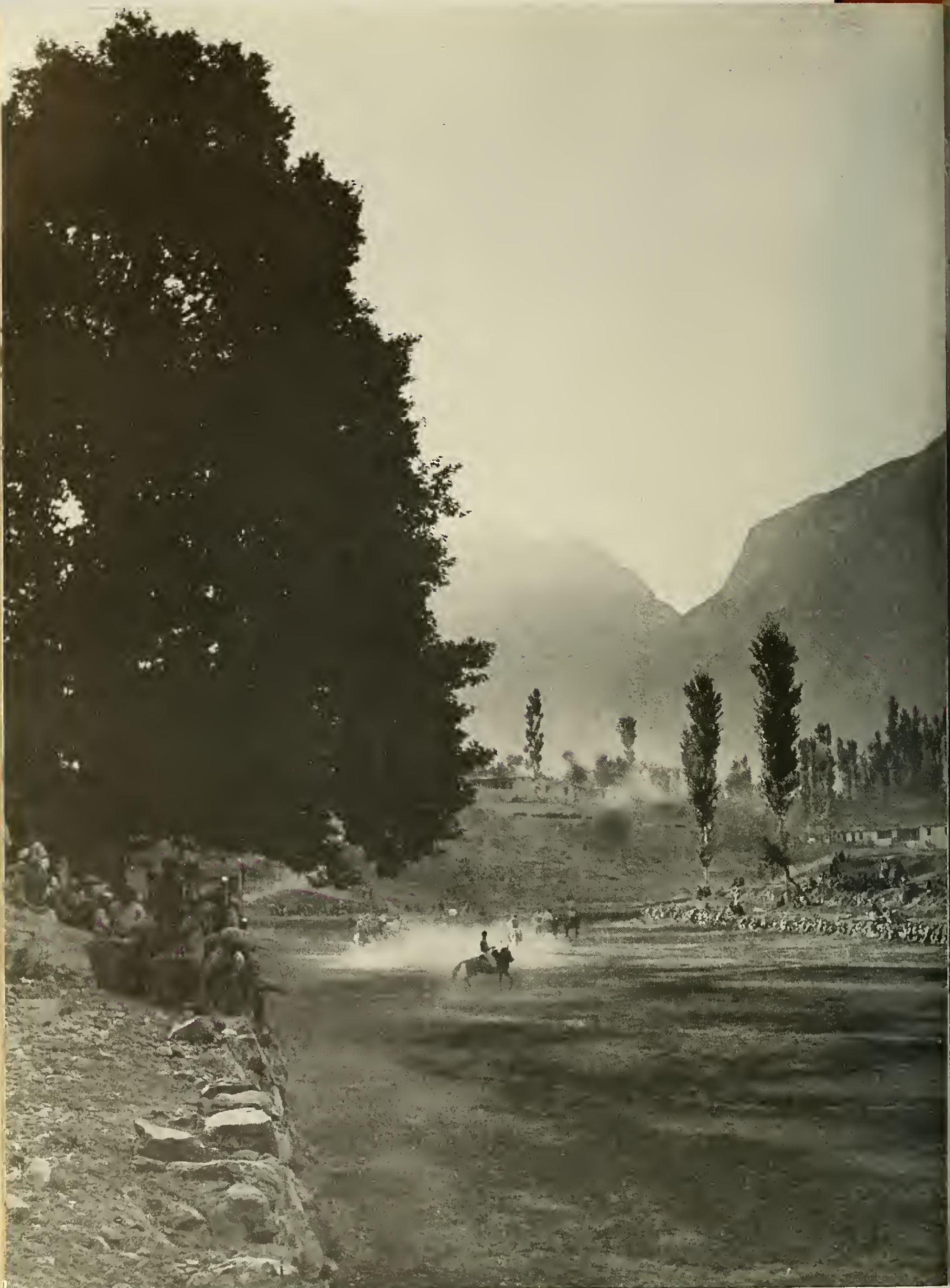


ASHING ACROSS A FIELD, Balti players ie in polo match. People of country claim game was invented in Baltistan. "Polo" means ball in the Balti tongue.

pper peaks, everyone is awake be-ause there is much to be done. The orning meal will come later, about n o'clock, but for the moment a hasty ack suffices—a handful of *yos* parched grain and roasted apricot ernels) or a drink of stewed apricot ice, anything that is handy. It is only e *kha-bor* (literally, 'push into the outh'). An appetite will come later.

TOOTHLESS *Api* (grandmother) is already carding a pile of Tibetan ool bought recently from the Bud-ists up the valley. Old Ali, tall and rather distinguished, is busy, too, for he has an appointment to sample a strain of tobacco in the next village. Ahmad and Marjan are finishing sets of homemade sandals, for they are setting out on the long road to India before the passes close. Money can be earned in faraway India, and on return a few extras can be bought for the home: perhaps a cow, some goats, and new clothes for all. It is the only way to make ends meet and pay the taxes.

"Gulbi, Abdul Kareem's wife, has been ill of late. While chasing a neighbor's goat from the roof, where she had left drying turnips, she had sunk her foot through the worn earthen surface and broken the poplar branches beneath. Her leg was badly torn. The local herbalist—the *awa*—did his part while feasting on one of Kareem's chickens. *Api* suggested a poultice of hot barley meal, and Kareem engaged a brother akhoond who writes amulets of potencies that correspond to the price. His amulet was tied to Gulbi's leg for some days, then was lost. The leg finally healed. Gulbi, however, is not risking a relapse, so she sits pathetically spinning yarn.



Major match at Skardu featured four of Baltistan's seven rajas as players. The country's few horses are more for prestige and polo than for transport.

"A glance at the sun reminds Gulbi that *zan* must be ready soon. Calling over the roof to her neighbor, she asks for *meh* (fire). A little girl reaches through the thorns and hands her a few embers in a broken piece of earthenware. To this Gulbi adds bits of rotted wood for tinder and soon her hearth is ready. The large copper caldron, half-filled with water, boils soon, and she throws into it several handfuls of roasted barley flour, stirring until the mix thickens. Hesitantly she takes a chunk of dirty white butter and melts it, carefully picking out the goat hairs. The family cannot afford melted butter every day. Gulbi does not have to call the family—they are suddenly there as she puts the steaming mass on a large metal plate on the floor. The family attacks the fat-rich food vigorously. Tomorrow the main meal will consist of *zan* accompanied only by a sauce of green herbs.

ON the mountainside across the valley, since first light, younger villagers have been busy cutting and uprooting *burtse* (wild artemisia). This dry-looking plant, invisible at a distance, is both the food of the ibex and the only free fuel the villagers can stockpile against the coming winter. Occasionally an apricot tree may be cut down or a small amount of cow dung dried, but *burtse* is the main solution to the fuel problem.

"On the way home, one of the young *burtsepong* (gatherers of *burtse*) sees an ibex and says he wishes he had a

EING AUTHOR, Balti spectators at a
lo match let gazes stray from game.

gun. A companion replies with a Balti proverb: 'The men who went out for *burtse* found ibex, the hunter found *burtse*.' Negotiating the ford is risky for the heavily laden men, but crossing by *zak* will cost money, and the winter bridges are not in place because the water level has yet to drop.

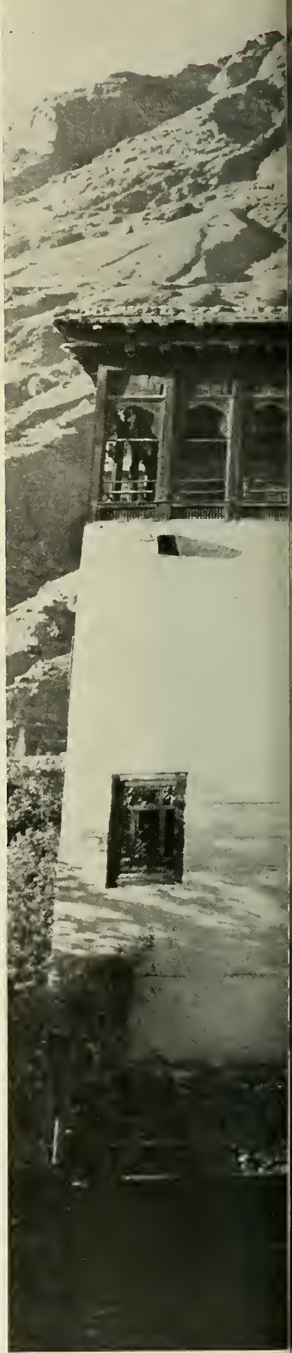
At one side of the hamlet, where two paths converge, there is what passes for a village square. The flat top of a very large rock, about nine inches above ground level, has two smooth holes in it that have served for generations as mortars. To one side of the stone two women are carefully cracking open apricot stones and collecting the kernels—the sweet *hrtsu* precious to the Balti because of their market value. Not long ago these 'sweet almonds' found their way to the hotels of India's larger cities. Cooks decorated cakes with them and ground them for a dozen different recipes. The Balti would bring them from every valley, in skin bags, to Skardu, where Sikh traders bought them. Now things have changed, and wheat flour brings the highest prices throughout the land. Other varieties of apricots—and there are many—also yield kernels, but these are pressed for oil.

"With little back-baskets (*chorong*) strapped over a sheepskin, and cloths over their heads, villagers carry night soil and pile it in various places in the fields. The night soil is of the utmost importance, since it is the principal fertilizer. The primitive latrines within and without the homes are kept reasonably inoffensive by adding earth and barley straw. Twice a year the latrines' stone walls are opened for removal of the contents to the fields. Only where the dried fertilizer is applied will anything grow.

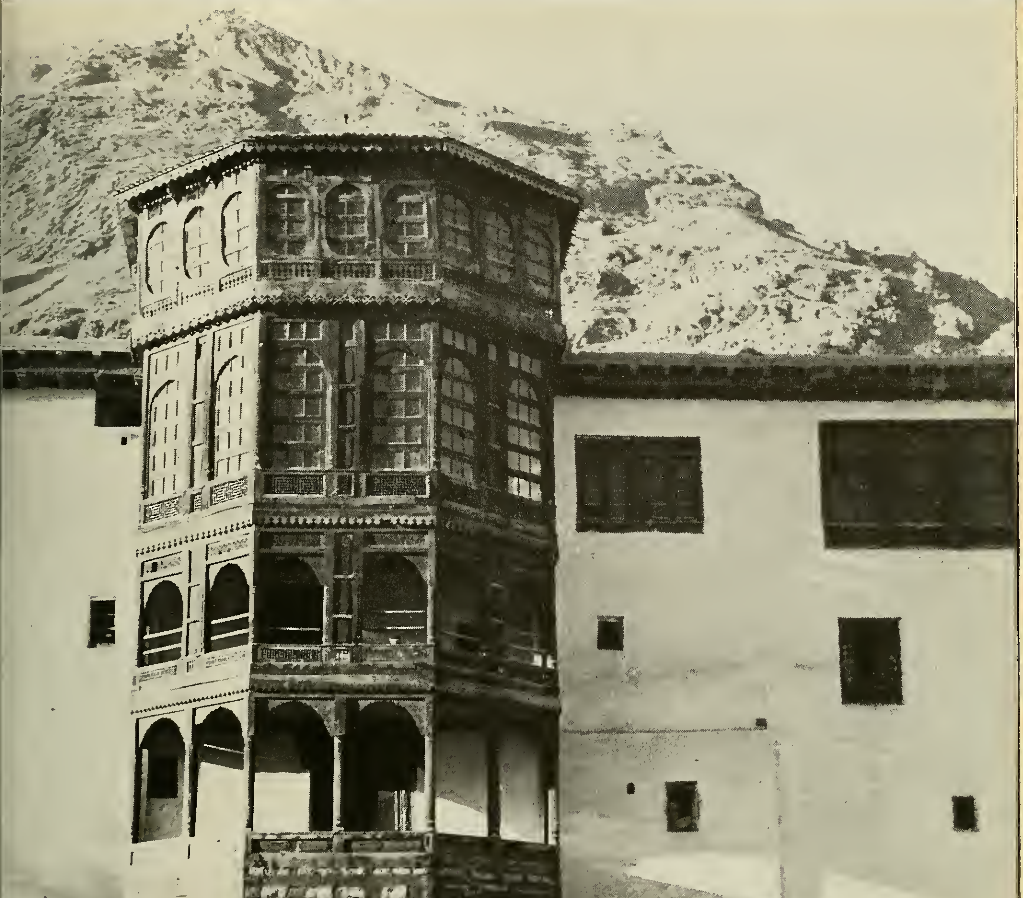
"Kareem has not been lazing around since *zan*. He has been busy with the wall round his fields. The slope of the land demands that the fields be terraced. Material for the walls is abundant—rocks, stones, and fragments of all shapes. Kareem knows that unless his retaining wall is firm his whole field will collapse when the irrigation water is turned on.

"The Balti has few games other than polo. Sode, an eighteen-year-old, has a riding horse. For months he has used every spare moment training it to take its place eventually in a real game of polo. Even if he cannot obtain an invitation to join the official teams that play on the big polo ground, Sode will go to watch the game and enjoy the music and excitement. After the match is over he is usually permitted to attend the players' tea party, where buttered tea is sipped while the merits and demerits of the other team's players are discussed.

Night comes, and dark mountains seem to fill the scene as a few villagers return from the mosque after the last prayer. The evening meal is ready. Although the menu rarely changes, there may be a treat tonight: homemade noodles or an egg. In spring there will be little to choose, but it is autumn now and the harvest is in. 'Eat, drink and be merry . . .' is the Balti's autumnal philosophy."



Covered passageway is a part of t
gate to house of the Raja of Khapal



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NATURE IN
ROCK & MINERAL

By Paul Mason Tilden

In past installments of this column we have used the word "pegmatite," without attempting any exact description of this most interesting lithologic phenomenon. We have indicated only that pegmatites—especially the granitic pegmatites often called "giant granites"—provide mineral collectors with some of their happiest hunting grounds. For it is in these coarsely crystallized dikes and bean-shaped bodies, frequently found associated with large intrusive masses of granite, that the hobbyist looks for such treasures as aquamarine, golden and pink beryl; black and colored tourmalines; many of the complex and rare iron, manganese, and lithium phosphates; columbium, tantalum, thorium, and uranium compounds; and a host of other collectibles.

Geologists, too, find that the unraveling of the mineralogical sequence of events within a large pegmatite offers a stimulating investigative challenge and a field for speculation, since, over the course of the "lifetime" of a pegmatite, remarkable changes and replacements of both constituent and accessory minerals may take place.

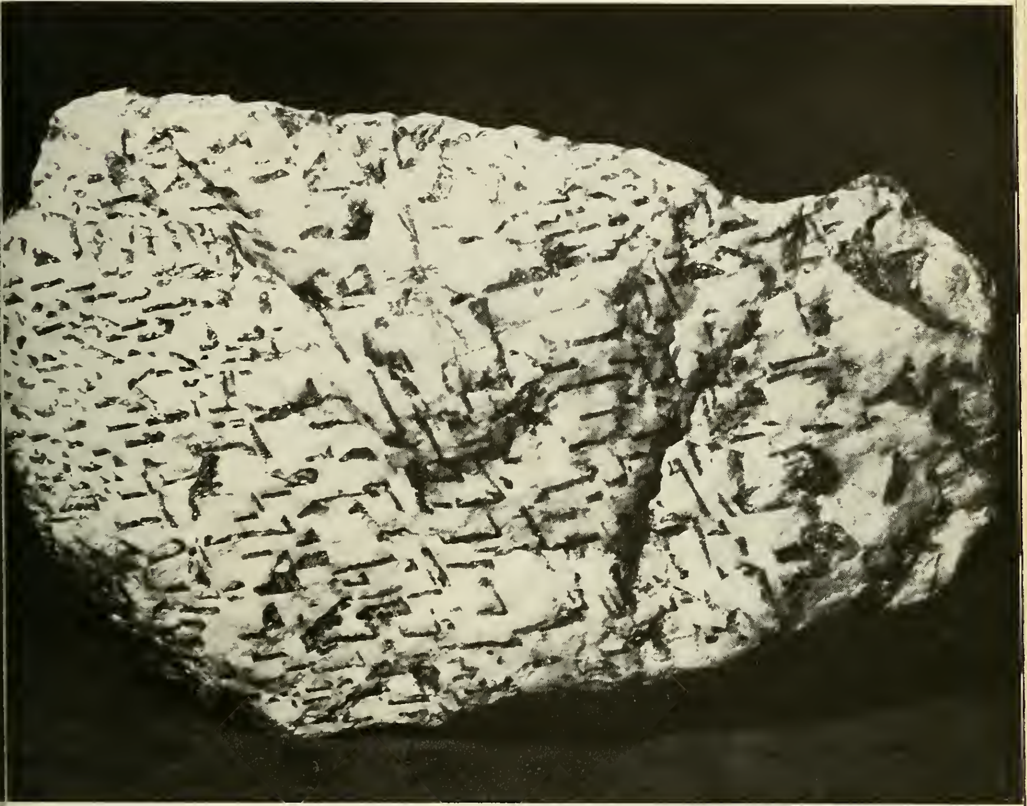
Finally, it should be noted that the granitic pegmatites are the source of several commercially important minerals—notably mica and feldspar—as well as several of the "newer" metals, like lithium and beryllium, which seem destined to play a key role in the successful harnessing of atomic power, as well as in man's projected exploration of space.

It is worth mentioning that many collectors think of pegmatites, essentially very coarse-textured phases of some rock types, as occurring exclusively in the rock we call granite, which is basically a mixture of quartz, feldspar, and mica. This is a mistaken notion, since pegmatites may occur in other kinds of rocks as well—syenite and diorite are two examples. However, since the pegmatites in other rock types are neither as common nor as productive for the collector, they need only passing mention here.

Most of our knowledge about pegmatites and the mineralogical changes that may take place within them is based on inference, petrographic study, and a knowledge of the chemistry and behavior of minerals. No one has ever witnessed the actual formation of a pegmatite, or the activities that may go on within one during its younger stages. Some of the minerals (such as crystalline quartz) that are found in such bodies have been created artificially in the laboratory. Yet the pegmatites themselves are formed within the crust of the earth under physical conditions that preclude human duplication. They are exposed to the attention of collectors and geologists only through the slow offices of erosion. In spite of this obscurity of birth and youth, however, geologists have a very well-formed notion of the processes that create pegmatites.

Over the course of geologic time, and doubtless continuing today, large masses of molten rock have locally eaten and pried their ways upward from the depths of the earth into its outer crust. There is presently no general agreement among geologists and other earth scientists as to how such molten masses originate and commence to move. It may be by the local relief of pressure on deep-seated rocks, the added heat of supposed movements within the earth's crust, the localized accumulation of radioactive heat at great depth, or by some other means.

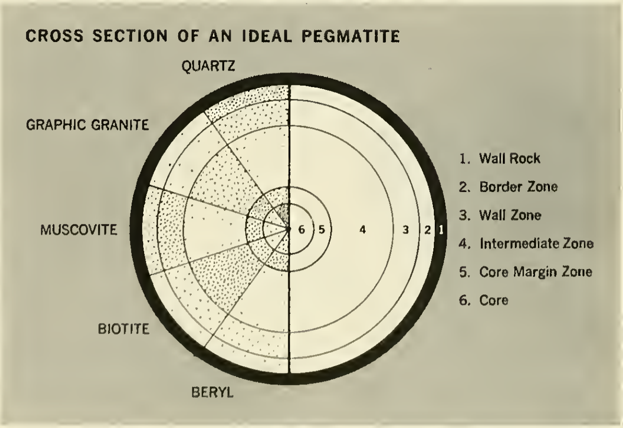
In any case, upon the arrival of such a molten mass in the outer part of the earth's crust, the process of cooling begins and the various mineral constituents of the mass start to crystallize, each according to its solubility in the fluid. Minerals like magnetite, apatite, chromite, and other basics, which are least soluble, crystallize out first, leaving a watery concentration of silicic and alkaline matter that includes such volatiles as boron, fluorine, chlorine, and small percentages of rare elements like beryllium, cesium, rubidium, columbium, lanthanum, yttrium, and others.



"GRAPHIC GRANITE," so named for strange markings that resemble hieroglyphics, has an oriented intergrowth of dark quartz that contrasts sharply with the white feldspar.

The whole fluid assemblage may be
reed into cracks and fissures in the
ck that surrounds the intrusion, and
rther crystallization takes place, even-
ally forming a pegmatite. Since the
lative size of individual crystals de-
nds in part, at least, on the rate at
ich the magmatic solution cools, min-
al collectors expect to find the largest
lthough not necessarily the most per-
ct) crystals toward the centers of large
gmatites, in which the total amount of
at to be lost to the environment is
eatest, and heat escape slowest.

ch of the pegmatite "liquor" as is
squeezed into the narrow fissures—
ging in width from an inch or so up
a foot or two—loses its heat rapidly.
d consequently the grain size of the
nite formed is very small. Small
ringers" or veinlets are commonly
ed with a fine-grained, whitish mix-
e of quartz and feldspar called
lite" by the mineralogists, but these


CROSS SECTION OF AN IDEAL PEGMATITE
QUARTZ
GRAPHIC GRANITE
MUSCOVITE
BIOTITE
BERYL
6
5
4
3
2
1
1. Wall Rock
2. Border Zone
3. Wall Zone
4. Intermediate Zone
5. Core Margin Zone
6. Core

STIPPLING indicates the relative density of some minerals (labeled at left) that are found in various sections of the onion-like interior-zoning of typical large pegmatite.

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Paul Mason Tilden, formerly an Editor of Nature Magazine and a rock and mineral collector himself, now continues his regular column in the pages of the combined magazines.

offer little of interest to the collector.

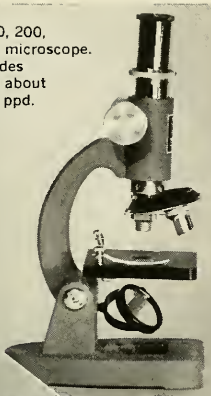
The fillings of larger fissures, which may be a yard to several yards in width, may exhibit coarsely crystallized quartz and feldspar crystals in their central parts, along with small "books," or crystals, of muscovite mica, small red or brown garnets, and an occasional small beryl. A pegmatite of this size might attract the casual attention of a collector.

It is the big pegmatites, however—those ranging from several yards to several hundred feet in thickness, and up to a mile or more in length—that delight the collector and furnish museums with rare or exceptionally large crystals. Concentrated within these bodies, in coarse, pod-like units, may be aggregations of large crystals of feldspar, quartz (sometimes of the amethystine variety), beryl, black tourmaline, mica, and perhaps a scattering of such rarer minerals as monazite, or uraninite and its brightly colored alteration products.

If a pegmatite exhibits a relatively rare alkaline-element phase, it may further afford the collector a number of the lithium-cesium-rubidium minerals; iron and manganese phosphates; colorless or blue apatites; columbite; the tin ore cassiterite: red, green, blue, or colorless tourmalines; pink, white, or ash-colored beryls; and such of the several lithium silicates and phosphates, like spodumene and amblygonite.

As examples of the great sizes that may be attained by the crystals of some big pegmatites, I once saw quarrymen blast their way into a "shoot" or "streak" (as such concentrations are known to feldspar quarrymen) in which many bushels of large feldspar crystals were loosely piled together like so many spilled bricks. In the same quarry, I saw a sheet of muscovite mica – actually a section of a larger crystal—that required two men to load aboard a truck! From pegmatites like this have come bery crystals weighing many thousands o pounds; feldspar crystals weighin tons; spodumene crystals measurin thirty feet long. Is there any wonder tha these bodies are called "giant granites"?

Many of the larger pegmatites, prob ably including a large percentag of economically important ones, exhibit well-defined interior zoning of textur and mineral components. In some suc bodies the onion-like zoning is so pro nounced that the skilled amateur is ofte able to locate his position within a quar



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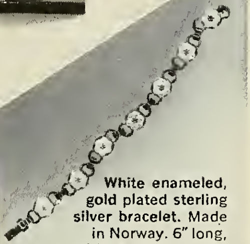

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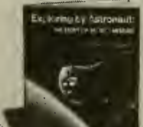

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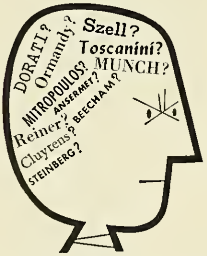
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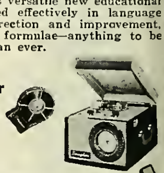

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ed pegmatite, in respect to the plan of e intrusion, merely by carefully ob-rving the texture of the nearby rock ılls and the minerals they contain.

HE part of the pegmatite that abuts invaded host rock is often called the *rder zone*, and usually consists of sev-al inches of fine-grained quartz, feld-ar, and mica. holding no particular izes for the collector. Next inward om the border zone of an ideal pegma-e (and ideal pegmatites are much sier to write about than to find in the ld) is the *wall zone*, the first really arse-grained "shell" of the mass, in ich individual crystals of feldspar in eir quartz matrix begin to be promi-nt. It is from the wall zones of large gmatites that a considerable portion of e valuable and strategically vital sheet "punch" mica of the electrical and ctronics industries is secured. Abun-nt black tourmaline. and perhaps an casional beryl crystal. may be found the wall zones of large pegmatites.

The next inner shell is called the *ermediate zone*. This portion of the gmatite usually abounds in the queer ergrowth of quartz and feldspar led "graphic granite." in allusion to occasional striking resemblance to cuneiform characters of ancient ies. If the black, iron-rich. and eco-mically worthless variety of mica led biotite tends to be prominent in a gmatite. it will ordinarily be found in atest profusion in the intermediate ie. Here. again. there may be a scat-ed showing of beryl crystals.

HE last two interior units of a zoned pegmatite are called the *core margin* d the *core*. In the core margin. there y be commercial concentrations of th muscovite mica and beryl. Quite en the core of a large pegmatite con-sts of a great blob of milky, rose, or oky quartz. with a large or small sprin-ng of large and handsomely formed dspar crystals.

This core, in which the quartz is com-nly of very high purity, is especially ractive to collectors. particularly those o make a hobby of cutting and polish-semiprecious gem stones. It is in and nediately adjacent to the core that the st and most transparent aquamarine yls are found; perhaps it would be re accurate to say. in the case of st working pegmatites. that tantaliz-fragments of these brittle gem stones to be found. for the miners' dyna-e, which uncovers the treasure, usu-almost destroys it as well.

An interesting phenomenon some-es associated with the core margins very large pegmatites is the so-called "ica-jumble," a rounding. solid mass small wedge-shaped mica crystals tan-d together in the greatest disorder. At

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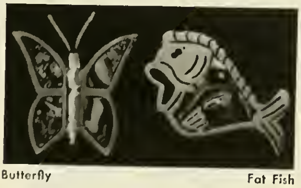

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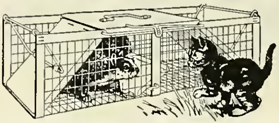

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the huge and historic Ruggles pegmatite in Grafton County, New Hampshire, there occurred such a jumble measuring some twelve feet thick and twenty feet long. While the A-shaped mica books found in such aggregations are worthless for any but the lowest commercial mica grade (called "scrap" in the trade), one might speculate, perhaps fancifully, that in such chaotic welters of mica lies the excess building stuff of the pegmatites—the material for which Nature could find no orderly purpose.

It is interesting to observe that many of the sheets and books of mica that occur in pegmatites are crystal "palaces" in miniature. Between the infinitesimally thin plates of mica crystals the mineral enthusiast may often discover crystals of beryl, garnet, magnetite, and other minerals, seemingly flattened almost into but two dimensions. Some of these possess no crystal form of their own, but instead conform in outline to the structure of the mica. Of interest, too, are the cracked, broken, or distorted crystals found in many pegmatites, giving evidence of the immense stresses, strains, and pressures that obtain during the formative stages of pegmatites.

ALL told, there is much to be observed and much to be learned during some exploration in the "giant granites." It is not difficult to determine the total yearly wealth, in tons and dollars, contributed to the nation's economy by the pegmatites. Millions of tons of feldspar, millions of pounds of mica, and a modest amount of commercial beryl are won every year from the nation's pegmatite mines and quarries; and these tons and pounds are easily translated into dollars. Not so easily measured, however, is the annual return to the nation's host of mineral collectors, whose rewards happily remain exempt from the ordinary ups and downs of the market place.

NOTICE

In next month's issue, the Editors will offer the second in NATURAL HISTORY's annual survey of children's books in the field of science. Of 115 juveniles published in this year, some 50 titles have been selected for critical assay.

This list details the photographer, artist or other source of illustrations, by page.

COVER—Charles Walcott
4—Joseph Sedacca
10—AMNH
12-19—Charles Walcott; except 14-15—AMNH
21-27—Lee Boltin; artifacts loaned by:
  22-23—Nasli Heeramanek, top; Joseph L. Costa, bot. 24—AMNH
  25—Museum of Primitive Art, top; AMNH, bot.
  26—Raymond Wielgus, top; Michael Kan, bot.
  27—Nasli Heeramanek
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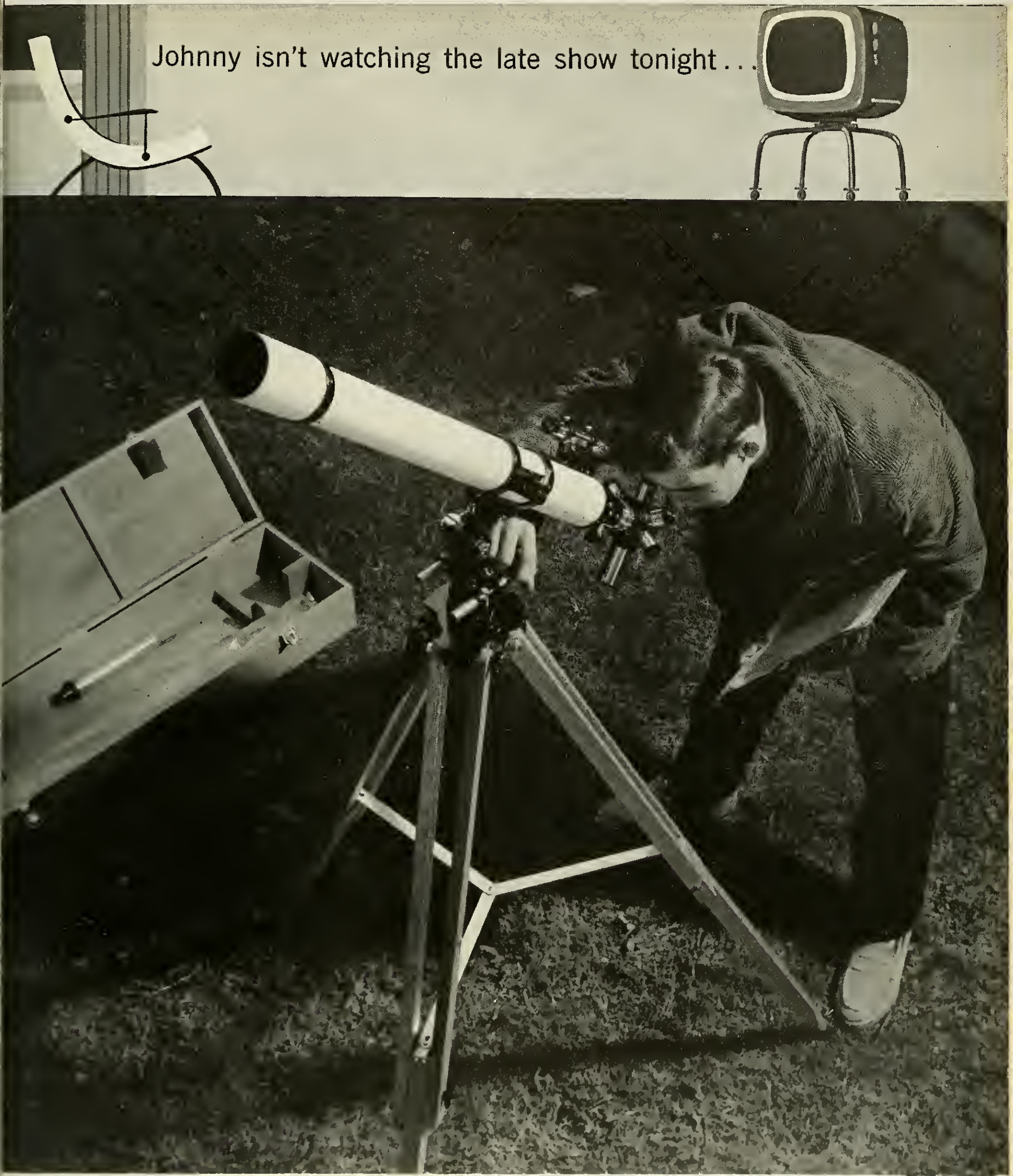
33—Stefan Martin
34-39—AMNH
44—AMNH
45—Lick Observatory
46-47—U.S. Navy
48-49—Star Map, after Henry M. Neely
50—Lee Passmore
52-53—Lee Boltin
55—AMNH
56-69—James Hurley
71—Paul Mason Tilden, top AMNH, bot.

Johnny isn't watching the late show tonight...



he shadows that shiver and shake on the TV screen are shivering and shaking in body else's living room tonight. Johnny has discovered something new.

e's traded the fleeting, flickering "thrills" of the 24 inch screen for the ss excitement and majesty of the night sky.

e's traded the nervous rattle of the private eye's gun for a ringside seat at upendous nightly fireworks in the heavens.

e has, in short, discovered astronomy.

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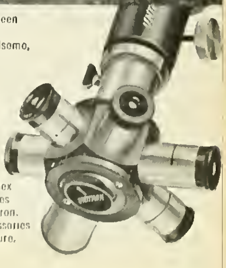

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We make a quantity of 1875 legs before we finish any holes in the base castings. The first step is to select drawn aluminum tubing at the Philadelphia warehouse of the metals supplier. We accept only those tubes whose diameters, including ovality, vary less than .003 inch. The lengths are then shipped to the Micromatic Company of Trenton, New Jersey.

Micromatic cuts them into short pieces and chamfers both ends inside and out. Then they centerless grind the entire outside surface to a tolerance of only plus or minus .0001 inch. One ten-thousandth inch. The group is then shipped to Pottstown, Pennsylvania, for a uniform, heavy anodizing, or sapphire plating, by the electrolytic method. This coating is actually quite thin, but very hard and durable for it is, being sapphire, of the corundum family. The 625 sets of legs, each alike in size to all the others within .0002 inch, are finally shipped to our factory at New Hope, where we make some parts completely and finish up others.

Meanwhile Micromatic has milled a long slot in 625 smaller tubes which slide inside the center tube and can be clamped at various degrees of extension. These smaller tubes do not need a close fit. A half-round block of milled aluminum alloy goes inside the slotted tube. One-half turn of a knurled knob will lock both tubes securely. Neither knob nor sliding tube can ever fall out to get lost.

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After the tempered sand castings have been cleaned by sand-blasting, they go to Gerald Fegley's shop in Pottstown, where he turns off almost one-half the metal in accurate machining. When turned to proper size on the engine lathe, Mr. Fegley himself puts them one by one in a large fixture which supports the piece and serves as guide while several holes are drilled, later to be tapped for fastening screws, and the three leg-holes are bored a trifle undersize. We have by this time sent several sample legs to Fegley and he has prepared a reamer and burnishing tool to ream each hole and burnish it to a mirror finish of exactly the desired size. When each piece is finished to his satisfaction, it is a handsome thing with no rough edge inside or out. Each is individually wrapped and shipped to us.

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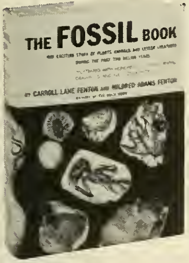
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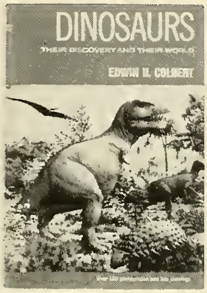
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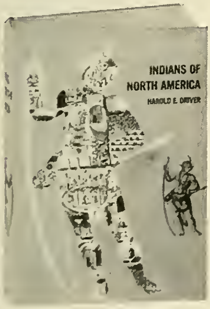
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The Story of
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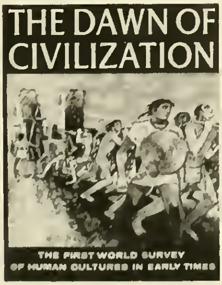
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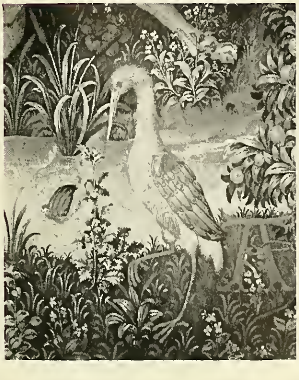

COVER: This heron is a detail from one of the marvelously wrought late Gothic tapestries called "The Hunt of the Unicorn," now hanging in The Cloisters, New York City. The popularity of this form of decoration derived from the almost nomadic life led by the aristocracy as they moved from one castle to another. Tapestries could be rolled up and moved, were less perishable than paintings, and lent warmth and color to drafty stone buildings. By 1500, the approximate date of these works, tapestries had begun to represent the natural world with a great degree of accuracy. For more about birds in the hangings, turn to page 28.

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MUSEUM MEMO

By John O'Reilly

N occasion a mother or father will say to us, "Some day we must take the kids and 'do' the American useum of Natural History." At such times, we realize ith regret, there are far too many persons who lack an nderstanding appreciation of the functions and scope of is venerable institution. It is impossible to "do" the useum in a day, a month, or perhaps a lifetime, for it sseminates learning and learning never stands still.

Those families that try to "do" the Museum in a day pend a lot of energy for the returns they get in terms of njoyment and knowledge. They traipse from hall to hall, lotting a minimum amount of time to each. At this rate, ey look upon the habitat groups merely as pretty pictures ther than careful, factual delineations of animal and ant life. In their haste they lack time to read the labels side the groups. They keep moving at a pace that tires e feet and dulls the mind. They are proud to have seen much, not even realizing how little they have absorbed.

There are much more profitable d enjoyable ways of doing this. r first suggestion is to slow down d take it easy. This Museum s been here almost a century d it will still be here a hundred ars hence. Take in only a few lls at a visit. Read the labels, look r details, spend enough time here each group to absorb its lesson. t down on one of those benches d gaze into a habitat group for a ile. You will find yourself wonring about the part of the world represents, even imagining that u are there yourself. Devote speal attention to such interpretative displays as the Warrg Memorial Hall, which treats of man's effect on his vironment—the world of nature about him.

Those who take it slowly and keep coming back for more scover new facets of the institution with each visit. They come aware that, although habitat groups are often the ain windows through which the results of scientific study d technical skill are seen, there are many other ways in ich the citizen may use the Museum.

For adults who seek a fuller interpretation of the exhibition halls there are the gallery talks. These are free d informal. An instructor meets the group, takes them to e hall concerned, and discusses the subject at length. bjects range from "The development and evolutionary max of the dinosaurs of the Cretaceous Period" to "The cient civilizations of Mexico and Central America." At a modest cost, the Museum provides various series of lectures, which are given in the evening and cover a wide range of subjects. There are also lecture series for members.

In the Museum auditorium there are afternoon motion pictures (which are free), including films designed for older children and adults or for persons of all ages. On Sunday mornings, over WNBC radio, Museum scientists tell of their own adventures in the search for knowledge. This radio program is called "Journey Into Nature."

Now that the space age has brought a growing interest in astronomy, The American Museum-Hayden Planetarium staff is meeting the demand with additional lectures for all age groups. They even offer a course in astronomy for engineers, a technical presentation designed to give physicists and engineers engaged in aeronautics and space exploration an orientation in various aspects of astronomy. There is also another course, of general interest these space-conscious days, called "Astronomy for the Family."

At dawn on a spring or autumn morning, bird watchers may be seen sallying forth from the Museum into Central Park. They are guided and instructed by Miss Farida Wiley, who has led bird walks in the park for years. It is astonishing how many species they find amid Manhattan's greenery. Twice a year Miss Wiley also leads groups behind the scenes in the Museum, taking them through the Exhibition Department and other sections to see how this citadel of science operates backstage.

There is almost always something going on in the Museum at night. Many local scientific societies hold their meetings in rooms provided for the purpose. Any interested person can drop by, sit in, and learn something. The meetings include those of the Aquarium Society, The New York Shell Club, The Linnaean Society of New York, the Metropolitan Grotto of the National Speliological Society, the New York Microscopical Society, The Amateur Astronomers Association, The American Orchid Society, and many others.

These are only a few of the ways in which the Museum maintains close and lasting contacts with its friends and members. There are many who have been visiting regularly since childhood. To attempt to "do" the Museum in one day is as foolish as trying to eat, all at once, the food necessary for a week's nourishment. A number of meals, spread over a longer period of time, make for a happier life.

Reviews

A Christmas survey of children's science books during 1961

A year ago, Natural History made its first annual survey of children's science books, a survey prepared by professional scientists associated with The American Museum. The Editors hoped that the reviews would help guide teachers, librarians, and gift-giving adults confronted with the task of choosing from a growing mass of material whose quality is uneven, to say the least. The response to that first survey was encouraging and indicated a need for continuing and, when called for, ruthless criticism by persons actively engaged in education and research.

This second annual survey discusses 44 of the 115 books received from publishers. Generally speaking, the reviews tend to be somewhat more favorable than they were last year, and I think that one reason for this may be a mild but heartening trend in publishing policy. More editors and writers are beginning to realize that books devoted chiefly to imparting facts rarely arouse a deep interest in science. Getting the facts straight and writing in an interesting style, while necessary, are by no means sufficient; these are simply basic, minimum requirements. The main task is delineation of the concept—the ideas and hypotheses that stimulate scientists to seek further knowledge. Concepts must make up the central element in any articulate and sophisticated account of science and scientific reasearch.

Books heavy on facts and light on ideas have been all too common. We have had books that tell all about stars or dinosaurs and little or nothing about stellar or organic evolution—as if science were merely a matter of describing and measuring and classifying. There is no more effective way of stifling children's natural interest in natural phenomena. Bare fact, even bare fact embellished by skillful writing, tends to have a flat, "what of it" quality. Facts may be easier to present than ideas, but that is no excuse for avoiding the real challenge. The problem is to achieve an appropriate balance between information and ideas, and efforts to solve this problem are evident in an increasing number of children's science books.

Incidentally, this trend has already progressed much further in our schools. More stress on ideas is a major feature of courses developed during the past five years by the Physical Sciences Study Committee and by similar groups concerned with the teaching of mathematics, chemistry, and biology. Indeed, the steady improvement of all aspects of high school science teaching is sure to have greater and greater influence in raising the quality of children's books that may serve as supplementary reading.

It should be noted that the federal government, acting through the National Science Foundation, has played a leading role in this development. The Foundation is also supporting the invaluable work of the Science Library Program of the American Association for the Advancement of Science. Among the Program's publications are "The AAAS Science Book List" for high school students, a revised and enlarged edition of which will be published early in 1962; "The Science Book List for Children," which is intended for students up to and including the eighth grade; and "An Inexpensive Science Library," a list of selected paperback titles. One criterion for selection in such lists has been whether or not the authors present their information against a sound and adequate theoretical background.

The reviewers in Natural History's survey are well aware of another extremely important criterion. Their most frequent adverse criticism, this year, concerns the quality of illustrative material. Last year, I pointed out that many publishers regard illustrations as secondary problems, putting off discussions with artists until the last moment, when there is no more time for art work that is at once informative and original. As a consequence, illustrations may be too few or mediocre; attractive, but empty and misleading. Like some people, such art fails to live up to a good first impression. A typical experience is the beautifully drawn diagram, complete with color, which turns out to be utterly confusing when it is studied closely.

Failures of this sort raise a number of serious questions. They would not exist, or at least they would be far less common, if scientists had been consulted well before publication, and had taken the time needed to review thoroughly illustrations—as well as text—from the standpoint of the intended reader. In other words, the publication of substandard illustrative material almost always indicates that no technically qualifie person has been intimately concerne with the all-important job of editing One might have expected that, by now such quality control would have becom routine, especially in science books an especially in books for children.

The disturbing thing, of course, i that the publishers involved are not living up to their responsibilities. On solution of the problem would be to employ trained science editors, specialist in the art of expressing technical idea in straightforward terms. A few publishers have already taken this step. Anothe step is to draw on the experience of scientific consultants, although experienc has shown that, by itself, setting u panels or boards of experts may not b enough. Consultants must be give ample time to consider manuscripts an illustrations, and to discuss details wit writers and artists. Equally important they must be well paid for their time.

In the long run, more attention wil also have to be paid to the problem o who is to do the writing. Relatively fe scientists have the time and qualifications to present technical informatio simply and vividly; relatively few professional science writers have the background required for preparing accurat and balanced reports on progress i complex areas of research. An approac that has produced good results is the us of both specialists—a collaboration between scientist and science writer. Plan to promote this approach are being considered by the recently formed Counci for the Advancement of Science Writing an organization that includes scientists publishers, and science writers.

Such developments suggest the scop of renewed efforts to improve children' science books. The search for imaginative; non-academic ways of describin research without technical jargon is jus beginning to gather momentum as specialists in all fields become increasingl aware of defects in current methods o communication. The reviews appearin below represent an important aspect o this search. Progress can come only b exposing new books to the critical examination of investigators, teachers, an others professionally concerned with imparting scientific information to nonscientists of all ages and backgrounds

John Pfeiffe

Astronomy

YOUNGSTERS, excited by the thought of traveling in space, seek more and nore information about space and asronomy. They must turn to books to satsfy this curiosity. Many of these books re good. but many are not. The medicre and bad books may be products of aste, designed to tap today's ready arket. Little can be done except to heed he caveats of reviewers. A worthy book eserves praise. Equally, if a book is unorthy, author, publisher, and public re entitled to the evidence that damns it.

Readers of *Satellites in Outer Space*, y Isaac Asimov (Random House), hould be about the fourth grade level nd interested in science. Professor Asiov, a notable and skilled popularizer, eviews the satellite program from the imple standpoint of "what good are an-made satellites?" He points out hat has been learned from several of ese bodies and from the deep space robes, as of 1960. He clearly defines any new terms (printed in bold face ype in a different color), then uses them ften throughout the rest of the book.

When writing for the very young, an uthor and his editor bear the responsiility of living up to the faith of the eader that what he reads in a book is the truth." If a concept is worth menoning, it should be explained correctly, owever simply this is done. Thus the uthor's brief reference to rocket gases ushing downward to raise a rocket is nfortunate. Also, the use of the one ord—meteor—to include the object in pace (meteoroid), the flash of light in e sky when it enters the atmosphere meteor), and the object when it hits the round (meteorite), will cause more nfusion in later years than would be aused if done correctly now.

But these are relatively minor flaws in n otherwise good book. Now that men ave actually traveled in space, a revised ition—to keep the material up to date is likely and should afford a good oportunity to make corrections.

The Milky Way Galaxy, by Ben Bova Holt. Rinehart and Winston), has a reezy style that should be well received by teen-agers. Mr. Bova is a journalist with a flair for science, and he lucidly explains the complex phenomena encountered in present-day astronomy and astrophysics. Unfortunately, however lucid, many of his own explanations are wrong, and the untrained reader (who else would read a book of this type?) will not be able to tell the very good from the very bad. Some examples of his more glaring errors follow.

Stellar structure and evolution are confused. Mr. Bova's explanation of the mass-luminosity law is impossible. The representation of the Hertzsprung-Russell diagram is crude and misleading. The "Biography of a Star" is incomplete, and the author has gone wrong on degenerate matter. Perhaps because the word "radio" immediately makes one think of hearing, radio astronomers are said to "listen in on the stars," a phrase that has no significance in radio astronomy. The true state of affairs is not complicated and a writer of Mr. Bova's ability should have been able to explain. Mr. Bova continues to go wrong in relating optical to radio electromagnetic radiation: ". . . since this window [in the atmosphere] is further down along the electromagnetic spectrum, these wavelengths are of less intensity than visible light, too weak for us to see."

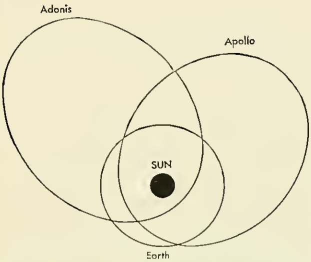


Diagram from *All About the Planets* shows the orbits of two "Earth-grazing" asteroids.

Many minor criticisms are possible: Ejnar Hertzsprung is Danish, not Dutch; W. W. Morgan and associates found evidence of our spiral arms, not W. W. Thompson, *et al.* In summary, Mr. Bova writes well, but he is so often wrong—apparently without knowing it—that the book must be considered a failure.

Astronomy, by H. C. King (Franklin Watts), is really a very good book. Dr. King writes for well-read, but astronomically innocent, high school students. The author is at home both in optics and in the history of astronomy, so these matters are particularly well done. The treatment of our present understanding of the universe, however, has not suffered at all in the process. The illustrations are mostly by Terry Maloney: his renderings of Mars, Jupiter, and Saturn are excellent. Mars especially is well treated; its appearance is almost as beautiful as it is in a fine telescope.

Very little adverse criticism of *All About the Planets*, by Patricia Lauber (Random House), is possible. The running title of this series is, of course, unfortunate: the book is *not* "all about" the planets, but it *does* tell a large fraction of the known facts about the planets and the solar system. To dispose of the venom first, a ride in a high-flying airplane should convince Miss Lauber that the earth's surface colors, other than a gray-blue, are difficult to discern when seen from space. And a rather strange picture is brought to mind by: "Titan's surface may be a jungle of methane glaciers. But this is only a scientific guess." Perhaps "jumble" was the word intended. And is a scientific guess better or worse than an ordinary guess?

That out of the way, it is very welcome to read a clear exposition of the several theories of the formation of the solar system. Often, in dealing with this difficult subject, an author merely presents the one or two ideas he happens to understand, even if these are completely discredited. Miss Lauber presents today's most popular hypothesis and shows that it is a natural by-product of star formation. She proceeds to discuss how this hypothesis implies that life in the universe may not be as unique as egotists may think. This is a worthy work.

The Doubleday Pictorial Library of Science—Chemistry, Physics, Astronomy is the first volume of a series that will constitute an encyclopedia of science, as the blurb says, for "our ideal reader, a boy or girl, parent, uncle or aunt, with a healthy interest in the external world." The publishers produced the book in England and Hans Erni designed and illustrated it. The result is beautiful and merely looking into this book makes one want to read and enjoy it.

Editorial philosophy has caused the subject matter to be arranged in a logical narrative manner, without making each topic too dependent on what has immediately preceded. The three fields

The reviews of current children's books in the field of science, presented on these pages, mark NATURAL HISTORY's second annual effort to provide guidance to gift-giving adults and more especially to librarians and teachers who are faced with the deluge of juvenile material, ostensibly presenting the sciences in factual fashion, which is poured onto the market each year. The 1961 score shows 115 such titles, of which 75 were deemed by the Editors to be worthy of scrutiny by its expert panel—five scientist-writers associated with THE AMERICAN MUSEUM. Of this 75, the panel rejected 31 out of hand. Presented here are reviews—by no means uniformly favorable—of the remaining 44. As in 1960, a general introduction has been provided by John Pfeiffer, himself an experienced science writer. The Editors hope that these annual assessments will serve as useful Diogenes' lanterns to all those seeking meaningful books.

of this volume—chemistry, physics, and astronomy—are treated separately, but many of the topics rightly belong to two or more fields. No sharp dividing lines are maintained, so the reader may discern the interrelations of science.

Most of the astronomy entries—of concern to this reviewer—were written by Patrick Moore, a well-known English amateur astronomer. He has rightly emphasized the amateur's importance to astronomy, and has shown the amateur's view. As a result, however, his treatment is purely descriptive, with seldom any exposition of the scientific importance of a subject. Thus, when discussing double stars, he mentions their beauty and the difficulty of observing some of them, but without stating that visual and spectroscopic binary stars provide the astronomer's only fundamental method for determining stellar masses—an exceedingly important datum in the theory of stellar structure and evolution. This sort of omission may be based on the author's opinion that the young reader should be encouraged to do only what he is now able to do regarding this thought-filled subject. It is possible, on the other hand, that the reader may, in consequence, gain the impression that astronomy is concerned only with a superficial description of the universe and the things in it, and thereby miss the tremendous challenge of astronomical research.

A curious lack of teamwork between text and art in the astronomy sections may be the result of hurry, carelessness, ignorance, or incompetence. Lack of time is the most likely explanation, but one or more of the other reasons is possible. Inquisitive young readers are certain to study this book in detail. If they find too many obvious errors, no matter how small, their faith in the correct, but unexplained, statements could be severely shaken. Certainly, their derision will be generated by the moon's appearance above the North Pole of the earth in a diagram of the tides, as well as by the North Pole's emanation from Siberia on seven other diagrams. They may also be skeptical of the way in which binary stars appear to bounce off each other. A future printing may allow these and other lapses to be corrected. We may also hope that the editors of future volumes in the series will have the co-operation of professional scientists as well as professional science writers. This volume and the series deserve the best from both fields.

Despite its catchpenny title, *Space in Your Future*, by Leo Schneider (Harcourt, Brace & World), is a really excellent review of astronomy—describing what is *already* in space. Mr. Schneider includes many simple experiments that will help young readers to understand some of the physical principles used by astronomers. The author stumbles into a few familiar traps—he includes cosmic rays in his discussion of the spectrum, and balances gravity with centrifugal "force." Since he does not make strong points of these items, the mistakes are relatively insignificant. It has been this reviewer's experience, on many occasions, to feel vicarious embarrassment on behalf of reputable astronomers whose help with a work of questionable value has been conspicuously acknowledged. The extent of their assistance—usually casual—is never really revealed. Whatever aid was given Mr. Schneider by the two renowned individuals he thanks, they have no cause for chagrin in this case. This is a good book.

Barbara and Myrick Land, the authors of *The Quest of Isaac Newton* (Garden City), have succeeded in presenting a little of the excitement of investigation and discovery in science by reviewing a few of the basic and far-reaching accomplishments of one of the best of scientists. As a footnote, it was part of the personality of Newton that he was slow to publish his works. In the case of gravitation and the moon, however, he had a different reason. The authors state that Newton knew that the earth's radius was 3,963 miles and that the moon was 238,857 miles away, and they imply that his calculations worked out exactly the first time. This was not the case. Newton first worked out the distance to the moon in terms of the earth's radius. By his theory, this ratio predicted a period of revolution for the moon that was observationally wrong. It was many years before better data on the earth's radius became available and his theory predicted the observations correctly.

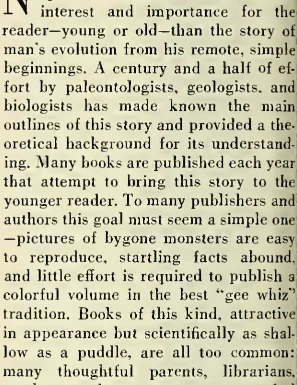
The design of this book will not attract the older readers that its vocabulary seems to require. It is doubtful that a student in junior high will be captured by art that has visual appeal only for the third grader. But perhaps he will remember the old saw that one should not judge a book by its cover.

Copernicus, by Henry Thomas (Messner), is a pleasure to read. Although working in novel form, the author has invented conversations that are always to the point, and that advance the story significantly. Nicholas Copernicus and his friends emerge as real people with real problems. The hero's enthusiasms and frustrations are shared by the reader because they are placed in context. Mr. Thomas traces both Copernicus' education and the background of his early thoughts on the form of the solar system, and depicts the precarious times and the dangers Copernicus faced should he openly espouse his revolutionary ideas. The patience and caution of the pioneer astronomer in his later years and his troubles with his superiors in the Church are clearly shown. His masterwork was finally produced as Copernicus lay dying, and Mr. Thomas outlines the slow but powerful impact it had on later astronomers—Tycho Brahe, Kepler, Galileo, Newton, and all to follow. One hopes Mr. Thomas will now give us as highly enjoyable biographies of Tycho and Kepler as he has of Copernicus.

KENNETH L. FRANKLIN

Geology and Paleontology

No part of science has more intrinsic interest and importance for the reader—young or old—than the story of man's evolution from his remote, simple beginnings. A century and a half of effort by paleontologists, geologists, and biologists has made known the main outlines of this story and provided a theoretical background for its understanding. Many books are published each year that attempt to bring this story to the younger reader. To many publishers and authors this goal must seem a simple one—pictures of bygone monsters are easy to reproduce, startling facts abound, and little effort is required to publish a colorful volume in the best "gee whiz" tradition. Books of this kind, attractive in appearance but scientifically as shallow as a puddle, are all too common: many thoughtful parents, librarians, teachers, and young persons must feel disenchantment when the textual content of such works is soberly assessed.



Method of locating earthquake's epicenter, diagramed in *Exploring Under the Earth.*

Happily, Robert L. Lehrman, the author of *The Long Road to Man* (Basic Books), is well informed, writes with style, and has exercised unusual perception in choosing and organizing his subject matter. The result is a distinguished ook. The essential outlines of the evoltionary story are well presented and the eader is given a real insight into the rocesses by which evolutionary changes ave been wrought. One excellent feaure of the text is that the author avoids versimplification. Many fossil discoveres, for example, are significant because ey give insights into the evolution from ne major group of animals to another, ven though they, themselves, do not lie irectly on the main line of descent. lany authors ignore this and tell a simler story—in which one group appears evolve directly into another. Mr. Lehrian manages to tell what is actually nown without confusing the reader.

The author has also wisely chosen to ocus attention upon major evolutionary ansitions, and to avoid the temptation f enumerating extinct curiosities not ssential to the main story. By careful election of material, he is able to give nough detail to allow the reader to unerstand the critical advances from jawss to jawed fish, from fish to amphibin, from amphibian to reptile, from reple to mammal, and from primate to ian. A concluding chapter on human volution invites the reader to reflect on ie meaning of what he has learned in rms of the future of the species.

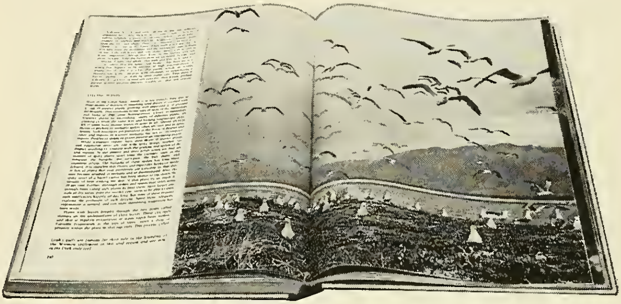
Only one feature detracts at all from is book: the illustrations may charibly be called adequate, but they do not dd to the effect. A pity: the text derves better support. Perhaps another lition will correct this flaw.

Like the preceding work, *The Wonerful World of Prehistoric Animals*, by /. E. Swinton (Garden City), aims to resent the story of life through the ges. However, a more striking contrast i bookmaking and writing would be ard to imagine. Swinton's book is comletely dominated by the illustrations, hich are superb in every respect. Striking photographs—many of them informtive color plates—are used with telling ffect, and drawings and diagrams posss both artistic and scientific merit. ltogether, the illustrations are superior those in most college texts and the relting volume will be thumbed through ith delight by anyone from 5 to 50.

Unfortunately, these illustrations are ll lavished on an undistinguished text written, paradoxically enough, by a disnguished British paleontologist). The ult lies in the author's choice of mateal, which represents an abridgment of opics normally covered in a college xtbook of historical geology. Each eologic period is named, and an abbreated catalog is given of events and anials characteristic of the period. One ay question if this is desirable, even in n adult book, but here the result is early unfortunate. To take one examle at random, the reader is informed (in vo sentences) that some Jurassic rocks in Britain are made of a peculiar limestone known as oölite, so named for the resemblance of its constituent grains to tiny eggs. True—and perhaps even interesting—but, in the context of this book, such a statement is more than useless: it merely distracts the reader.

A fault more serious than the inclusions of such bits of gratuitous information is Dr. Swinton's failure to dwell on the vital processes of evolution revealed by the fossil record he is describing. For example, the transition from amphibian to reptile is dismissed in half a dozen sentences, while the dramatic and instructive aspects of the return of reptiles to the sea go altogether unremarked. The over-all effect of the book, alas, is little more than that of a colorful parade of amazing animals.

The Earth, by W. B. Harland (Franklin Watts), is intended as a general introduction to the study of the earth, including those rocks, minerals, and fossils that may be collected by the amateur naturalist. It is aimed at an audience 14 years old and older. Unfortunately, it is both poorly organized and poorly illustrated, and it incorporates most of the bad features of current college textbooks. The book opens with a brief history of geology that is difficult to grasp



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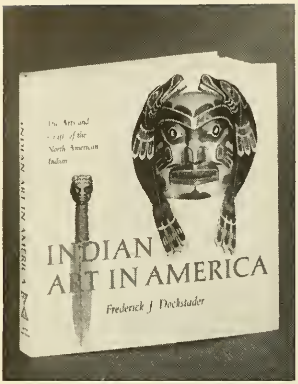

INDIAN ART IN AMERICA

The Arts and Crafts of the North American Indian

By Frederick J. Dockstader, Director of the Museum of the American Indian, Heye Foundation, New York, and Commissioner of the Indian Arts and Crafts Board of the U.S. Department of the Interior. 70 color plates and 180 black and white illustrations. 224 pages, 10 by 11 inches. Boxed. $25.00

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Robert Bruce Inverarity,
New York Times Book Review

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Lee Ash, *Library Journal*

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A major contribution to the field of Indian studies. Oakland Tribune

One of the most magnificent art books of this or any other year.
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unless the reader already possesses advance knowledge of geologic principles. The author then goes on to treat such complex topics as isostasy before the reader is given a chance to absorb more elementary principles. Many of the illustrations are difficult to understand and, frighteningly enough, appear to have been done without firsthand knowledge of rocks or landscapes.

Exploring Under the Earth, by Roy A. Gallant (Garden City), is an attractive book, aimed at readers of ages 10 to 14. Mr. Gallant presents the story of the earth with emphasis on the more recent findings of geophysics, particularly regarding the ocean's and the earth's interior. The author has shown keen insight in selecting topics that are of major scientific importance and are in the forefront of modern research. His list includes such matters as the earth's origin, its shape and size, features of the ocean floor, the origin of continents, island arcs, earthquakes, volcanoes, the origin of mountains, and many more. In fact, the book's chief drawback is that the author has attempted to cover too much in the space available. The result, in some parts, is a slapdash treatment of one topic after another. In six paragraphs, for example, the author covers the topography of the ocean floor, the composition of oceanic crust, continental drift, submarine canyons, and turbidity currents. Where greater space has been allotted, as for earthquakes and volcanoes, the text is much sounder.

Mr. Gallant has not hesitated to present explanations for many phenomena that are no more than untested hypotheses. In each case, however, the source of the theory is given and the hypothetical nature of the explanation noted. The over-all effect of the book will surely be to stimulate young imaginations and to make it clear that many challenging problems remain for future scientists.

Mountains on the Move, by Marie H. Bloch (Coward-McCann), is an attempt to present the story of the earth briefly and simply to the 8- to 12-year-old reader, with emphasis on processes and events that can be witnessed on walks and trips. Several early chapters, covering basic processes of weathering and erosion, are well done and succeed in conveying their importance and reality to a young audience. Here, the photographs are well chosen and the text clear. For the most part, however, the book falls wide of the mark. There is a complete absence of diagrams, a fatal weakness in a book of this sort, for many concepts in geology are basically geometric and require diagrams for explication. An attempt is made, for example, to describe the erosional history of the Rocky Mountains by words alone. Also, erroneous or misleading statements occur too frequently. Mark it: "failed."

Wonders of Rocks and Minerals, by R. M. Pearl (Dodd, Mead), purports to be a guide to the wonderful world of rocks and minerals. Unfortunately, it is poorly organized and startlingly incomplete. In the chapter on sedimentary rocks, for example, the commonest of all sedimentaries—shale—is not even mentioned, but four paragraphs are allotted to that obscure, if spectacular rock, itacolumite. Equally puzzling is the lack of illustrations of rock and mineral specimens. Of the dozens of possible specimens, only five are illustrated at all: tourmaline, quartz, feldspar, diamond, and (of course) itacolumite. Another book, then, to be marked as "failed."

Ice Age Coming?, by L. G. Richards (John Day), devotes its main portion to an interesting, well-illustrated, informative, and up-to-date account of icebergs, glaciers, and icecaps. With this material the author obviously has firsthand experience, and the result is very good. It is unfortunate that the book, as a whole, is marred by a confusing and often inaccurate coverage of the geologic background and significance of glaciers. We are told, for example, that ". . . 50 million years ago . . . huge cold-blooded reptiles from the depths of the sea ruled the land" and that, without glaciers, "... mountains would be only flat, dull hills." On balance, a low "pass."

The Doubleday Pictorial Library of Nature: Earth, Plants, Animals is a companion volume to the *Pictorial Library of Science*, reviewed, *above*, by Dr. Franklin. The stated objectives of this second work in Doubleday's series are breathtaking in their scope: "... a description," says the publisher, "of the seas and crust of our planet Earth ... the story of how they came to be what they are . . . a description of the planets and animals of the earth, and the story of how they evolved . . . a description of the web of life, and the story of how man arose, to become part of it, finally to dominate it." Whew!

Perhaps the most striking feature of this very unusual book is that its grand objective is in fact nearly achieved, so far as this reviewer's fields are concerned (comments on the work's competence in the realms of biology and ecology will be found on page 9 among Dr. McCormick's reviews). So far as geology and paleontology are concerned, the material is in general presented with clarity, literary style, and accuracy. The diagrams and photographs, many in color, are superb; without them it would have been impossible to compress so much in so small a space.

In spite of the enormous coverage of this book, the editors have managed to avoid oversimplification. Technical terms are used unashamedly and the reader is brought to grips with the essential details of many structures and processes.

This commendable virtue, however, restricts the audience to high school and older—rather than the younger—readers.

A few weak points are almost inescapable in such a work. In part this is a reflection of the much shorter space given, for example, to astronomy and geology, when compared to the biological realm. For astronomy, of course, the reader may turn to Doubleday's other volume. Even so, the opening paragraphs on the universe, for example, contain so many facts in such short space that a beginner's comprehension will surely suffer.

In the geological sections—which are treated in this volume alone—the problem is even more serious. Unless one sentence in one caption for an illustration is read with care, for example, the reader will be misled into believing that features of old mountain ranges result from slow, simple wearing away of a primary jagged landscape. Similarly, the book gives an entirely erroneous impression of the distribution of gravity near continental margins, and the section on rocks is quite inadequate.

In spite of these shortcomings, this prodigious book, in the reviewer's opinion, stands as the best single volume available for serious students seeking a comprehensive view of these fields.

In many parts of the world, at home as well as abroad and in humid lands as well as arid, conservation and management of water resources have become a major social, political, and economic problem. Although the scientific study of this problem must begin with an analysis of the geologic water cycle, for a full appreciation of the problem the student must treat ecological and political questions as well. *Water for the World*, by Elizabeth S. Helfman (Longmans, Green), is one of three books reviewed here that seeks to give the young reader an understanding of many sides of the water problem. This little book is a good, easily read volume that covers many aspects of water, including its chemical nature; the dependence of man on water; irrigation problems and techniques; problems of bringing water to cities; floods and droughts; and the industrial uses of water—as well as a summary of the TVA. Although the book needs more illustrations, the reader is unlikely to take water for granted again.

Water for People, by S. R. Riedman (Abelard-Schuman), is a small, ingeniously written and ingeniously conceived book on water and water problems for the 8- to 12-year-old reader. The book's most striking feature is the consistent use of inductive reasoning. The simple observations and experiments described will delight many youngsters and lead them to a firsthand understanding of physical principles and processes relating to water in all its manifestations.

Exploring the River, by John and Jane Perry (Whittlesey House), presents the message of conservation of water resources, described through the medium of a hypothetical exploring trip. The main theme of the book—the interdependency of all life—is well brought out.

JOHN IMBRIE

Botany and Ecology

This year has seen a flood of gilt-edge mediocrity issue from several large publishing houses. Relatively weak texts and undistinguished illustrations are combined, and then inflated by excellent design and lavish use of color to produce eye-appealing books that doubtless will find their way into many American homes. This is presumably counted as a success in a business sense, but for natural history education the gain is dubious. Perhaps it is better to have a mediocre nature book in the home than no nature book at all. But how much better it would be to have books of quality written (or, at least, critically appraised) by responsible authorities. Such standards are not difficult to attain but, to achieve them, publishers must recognize their obligation to the public.

As an example, *The Golden Picture Book of Nature Walks* by Clara Hussong (Golden Press), is supposed to be an introduction to the field natural history of eastern North America. The work is organized basically around the major habitat types—field, forest, and pond—but the sections on each of these habitats is subdivided along taxonomic, rather than ecological, lines and contain separate discussions of mammals, birds, reptiles and amphibians, insects, and plants. In addition, other sections describe a stream habitat, poisonous plants and animals, and the biological changes associated with the four seasons of the year. All in all, a commendable enterprise.

But let us consider the negative aspects of this book. Although there are many drawings, a number of the plants and animals mentioned in the text either are not illustrated or else are not adequately labeled in complex, multiple-subject illustrations. Thus, the reader's familiarity with nature is presupposed. These illustrations, moreover, are often simply arty, lack detail, and vary in accuracy from one page to the next.

The author, in turn, has fallen into the vulgar error of equating the word "animal" with "mammal." She grates the ear with such strange combinations as "insects and animals," and "animals and birds," while mentioning mammals alone in sections on "field animals" and "animals that live near water." The text is further marred by statements both teleo-

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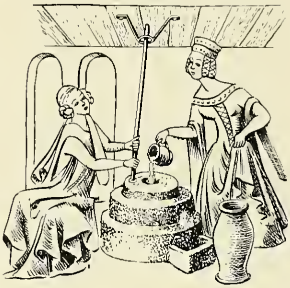
logical ("most field birds are dull-colored for camouflage") and anthropomorphic ("some [plants] *like* dry, sandy soil"), as well as a number of errors ("The giant sequoia trees of California are the oldest living things on earth"). All is not gold that glitters.

A less gilt-edge but infinitely better, more accurately written, and superbly illustrated book is Henry B. Kane's *The Tale of a Pond* (Knopf). This is a companion volume to Mr. Kane's *Tale of a Meadow* (reviewed in last year's Christmas survey). His new book is an intimate description of the variety of life in a New England pond, of the activities of various organisms during the year, and of the evolution of the pond community. The story is told in terms of a young boy's visits to the pond, but the author does not burden the reader with far-fetched adventures, trite dialogue, or a creaky "plot." Instead, we have a sympathetic, well-contrived, and smoothly written narrative by an impersonal observer. Obviously Mr. Kane is intimately acquainted with the pond of which he writes. His sketches and photographs are outstanding and are well correlated with the text. With the author's remarkable ability to see the dynamic side of everyday life in a natural community, as well as his talent for sketching, photography, and writing, we hope to see other books by Mr. Kane in the future.



Medieval maidens make flour from grain in hand mill—from *Harvests and Harvesting.*

Only those parts of the *Doubleday Pictorial Library of Nature* that deal with general biology and ecology are considered here. In these fields, at least, the quality of the volume's illustrations varies from outstanding to poor. The diagrams generally are excellent. The photographs are abundant and usually good, but are poorly printed. Alas, the sketches, particularly those of animals, are stylized and artificial, while the maps are inexcusably inaccurate in their depiction of land masses. Finally, the illustrations are not well co-ordinated with the text—in spite of a claim in the preface that there is a "special relation of text and pictures." An example of this is one section in which the text describes the vegetation succession on a lake in North America, while the accompanying diagram shows (poorly) the belting of vegetation around an English farm impoundment and its feeder stream.

The quality of text in the biological sections of the *Pictorial Library of Nature* is generally good, although the purportedly logical arrangement of subject matter of the volume is more nearly a potpourri of natural history. As one might expect, so vast a subject is difficult to present in this book's relatively few pages. Many concepts are introduced, but not clearly distinguished (examples: fauna versus population, flora versus vegetation), or not defined (example: pyramids of numbers and energy). A number of basic concepts, such as food chains, food webs, and ecological dominance, are not even mentioned. Too, the accuracy of the text fluctuates from page to page. When it deals with general principles, the written matter is usually adequate. But when North American examples are cited to illustrate a concept or to serve as a concrete example of an abstract community, the accuracy falls off.

The least accurate section is entitled, "The Web of Life." Here we are told, erroneously, that a beech-maple forest is the climax forest in North America as "other parts of the Temperate Zone"; the Eurasian reindeer and American caribou are said to be the same *species;* a deciduous tree is said to grow only while in leaf; the star-nosed mole is called a typical dweller of the deciduous forest; box turtles are said to inhabit streams, and the skunk is called a reptile (presumably "skink" was meant). Among various other tidbits of unnatural history, all plants here are said to need soil and light and all bacteria make their own food by chemosynthesis.

In the book's discussion of desert life, one is given the impression that plants survive in these arid lands only by storing water in succulent tissues. Drought resisting and drought-escaping plants—which actually form the bulk of desert vegetation—are ignored. In discussions of habitats, such as deserts or grasslands, organisms from all parts of the world are listed in an indecipherable jumble that leaves one with the impression that they may all live side by side and enjoy catholic distribution.

From all this it is evident that the *Pictorial Library of Nature* falls short of perfection. Although many of its sections are clear and accurate, these are offset by others that contain gross inaccuracies and confused exposition. The young reader or adult layman cannot be expected to distinguish between technical accuracy and technical incompeence. It is, therefore, impossible to ecommend the first edition of this work. t is hoped that many changes can be nade in subsequent printings and that complete revision will be made in the ear future. It would ease the task reatly if an American naturalist were dded to the editorial staff that under- akes this much-needed revision.

Harvests and Harvesting through the *ges*, by Norman E. Lee (Cambridge), s a survey of the development of agri- ulture from the time of primitive man o the present. The text, alas, reads like B.B.C. Third Program broadcast. It is nduly dull, pedagogic in style, repeti- ive, and poorly co-ordinated. But the uthor's story, for all that, is fascinating nough to hold the interest of any eader, young or old. Throughout the vork, one is impressed by the impor- ance of knowing the ecology of culti- ated plants and domesticated animals.

It is only fair to warn prospective pur- hasers that Mr. Lee's book presupposes familiarity with many aspects of his- ory, which have influenced the develop- nent of and the demand for farm nachinery. The history of civilization, ocial reforms, wars and concommitant r shortages, and the general advance f technology all play important roles.

The harvest of timber crops is not nsidered in Mr. Lee's book on harvest- . But Charles I. Coombs presents an ellent elementary survey of forestry n America in *High Timber* (World). he well-organized text describes the levelopment of scientific forestry, the iology of trees, the organization and esponsibilities of the United States For- Service, methods of forest harvest, he utilization of wood and manufacture f wood products, watershed protection, orest wildlife production, forest recre- tion, fire control, insect pests and tree liseases, and careers in forestry.

Here and there, Mr. Coombs falls into rrors of omission and may even be uilty of slanted reporting. For example, n discussing forest fires, the author ade- uately covers both the tremendous dam- ge done by wildfires and the damage lone by fires set deliberately—to "green p" the grass in forested pastures, to im- rove berry crops, and for other reasons. lowever, he goes on to condemn *all* ires, and fails to mention the growing ilvicultural use of prescribed fires, or ight winter burns, of proved value for he production of proper seedbed condi- ions among certain commercially im- ortant tree species and for the elimina- ion or suppression of some "weed" trees.

A more striking instance of slanted eporting is the author's discussion of vilderness areas in the national for- sts. Mr. Coombs pays lip service to a ew of the aesthetic values of such large atural areas, protected from the en- roachments of timber-cutting, stock-grazing, and other human intervention. However, no mention is made of these areas' unequaled — and irreplaceable — scientific value as standards of reference for biologists and foresters, and as biological reservoirs in which many micro-organisms and larger life-forms may survive the onslaught of civilization and its attendant disturbances.

While the values of these areas are thus weakly presented—essentially as playgrounds for a few venturesome souls —the case *against* wilderness areas is stated firmly and, to one not aware of the other side of the picture, convincingly. Mature, commercial timber stands unharvested, overripe trees are left to die of old age, insect damage, or disease, and to rot when they fall; rushing streams, capable of producing untold amounts of hydroelectric power, waste their energy by bubbling over remote boulders and cascading down waterfalls far removed from highways and cozy picture windows.

To find fault with a few pages, however, is not to condemn this book. On balance, Mr. Coombs has made a significant, positive contribution.

JACK MCCORMICK

Zoology

CHILDREN'S zoological books are on their way to coming of age. This year, there are many fine choices for the young reader and, on the whole, the books are dignified and intelligently written. Gone are the adjectives (cute, quaint, adorable); gone are the anthropocentric descriptions. Instead, many authors prove that there can be great excitement in learning about living things simply because they *are* living, because of their habits, their ways of life, and their sometimes incredible means of adapting to their environments.

In addition to books on animal life, moreover, this year we find clearly written books on the "how to" of scientific experiments, as well as books on subjects that were formerly offered only to adults—about oceanography and marine biology, about such advanced biological principles as animal clocks and rhythms.

One disappointment is the illustrations in a number of these works. A child's book of zoology without illustration is almost useless, yet many illustrations in this year's crop are so poor that they might better have been omitted. Sketchy, slovenly, many pay little or no regard to the details that often add the necessary dimension of beauty.

A glaring example is *Meadows in the Sea*, by Alida Malkus (World Publishing Co.). This book could have been the younger set's version of Alistair Hardy's adult classic, *The Open Sea*. But the il-

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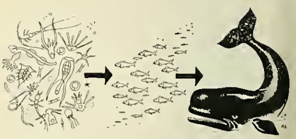
lustrations are so soft and look so much alike that the impact of the diversity and the beauty of these myriad drifting marine plants and animals is lost. These illustrations beg accuracy to the point where one suspects they were rendered by someone who never saw plant or animal plankton: they are pathetic. A further paradox is that type and layout of this book evidently were designed for the younger child (third or fourth grade), but the scientific terminology and the levels of explanation are directed toward a far more sophisticated reader—one who knows the principles of animal and plant classification. Too, Mrs. Malkus assumes that the explanations of activities are implicit in their mere description, as when she recounts patterns of plankton movement and diurnal migrations, but does not make clear what kind of plankton she is describing.

Two of the four other books about the sea are surveys of oceanography and marine biology, with emphasis on the techniques of exploration and some of the discoveries. *All About Undersea Exploration*, by Ruth Brindze (Random House), is a survey of some of the historical and modern methods of oceanography—techniques for depth and temperature recordings, for geological surveys, and for the study of currents (including some up-to-date material on the Swallow buoys that measure deep currents). Mrs. Brindze also describes research vessels, Scuba diving, treasure-hunting, drilling for underwater oil, cable placement, and the like. It is a pity she felt it necessary to cover all those subjects. True, they are related to the oceans (in that they take place at sea) but should they be considered as part of undersea "exploration"? I don't think so. The inclusion of so many subjects is likely to leave the young reader at a loss to decide where exploration ends and exploitation begins.

The Challenge of the Sea, by Arthur C. Clarke (Holt, Rinehart and Winston), is more fun to read than Mrs. Brindze's book. Mr. Clarke, who has been writing children's books for many years, knows his trade well. He elicits a sense of participation in his reader and manages to bring him to the brink of great new discoveries, which will occur only if the reader himself makes a career of oceanographic research. This is exciting. What better way to entice a child! Mr. Clarke's subject matter overlaps, to some extent, Mrs. Brindze's "*Allabout*" treatment. He presents both historical and up-to-date surveys of the techniques of sea research. But he carries the story further, delving into ingenious and daring developments in ship design, underwater exploring craft, hydroplanes, and fishery techniques. He takes his reader into an imaginary future when men will "become fish" and live under water for long periods of time. There are science fiction seascapes and illustrations of some of the lesser known creatures of the deep. Unfortunately, in some, the artist has overlooked accuracy for sake of drama, or even for no reason.

Searchers of the Sea, by Charles Daugherty (Viking), is an exciting narrative tale about explorers—not only the mythical and real ones who sailed ships across the oceans to find new routes to fortune, but also the scientists who discovered how the oceans moved, measured the tides, the currents, and the wind patterns, and sent instruments to probe and sample the ocean depths. Mr. Daugherty points out how difficult it once was to understand things we take for granted now—such as direction of currents. He relates how long and arduous and searching this task was less than two centuries ago. Ships were the only means of crossing the ocean, yet no one understood why it took two weeks longer to go from London to New York than to go from London to Rhode Island. A study of this puzzle led to the discovery of the Gulf Stream. Mr. Daugherty writes about Banks, Nansen, Agassiz, Manx, Iselin—the men who laid the foundations of modern oceanography. He writes about the famous oceanographic vessels, *Endeavor* and *Challenger*. The people not only come alive in his story; they are inspirational.


PLANKTON *to* KRILL *to* WHALE

Absurd error in illustration—shrimplike krill are drawn as fish—shows the urgent need for intelligent editors. Mistake mars a worthy book—*The Challenge of the Sea*.

Under the Sea, by Maurice Burton (Franklin Watts), is an encyclopedia of the many species present in the oceans from bottom to top. Described are the algae, the plankton, the invertebrates and vertebrates, the life of the shore, of the shallow seas, and of the deep. Dr. Burton does not shy away from scientific names, mentioning them after he has given the common names. As I read the book, I wondered where it would fit in. I think that it will be a good reference for junior high school students. It will not assist a collector, but it will help a student who wishes to know a little more about a particular fish or invertebrate. It is well illustrated with line drawings and very pretty watercolors—in which many of the colors are close to reality.

The Quest of Louis Pasteur, by Patricia Lauber (Garden City), is a flowing biography about one of the greats of all time. Pasteur is a classic scientist—a man who was discouraged and encouraged; a man whose experiments did not always work; a man who experienced apparent sudden insight leading to brilliant solutions of his bacteriological problems. He was a simple and humble man, to be greatly admired and praised for his intense devotion to his work. The author, while filled with appropriate admiration for Pasteur, has overwritten her praises: Pasteur emerges not so much a human as a superhuman—a high standard for any child to hope to emulate. However, aside from being abundantly stocked with such phrases as "burning with curiosity," and "blinking in astonishment," this is a good book. In its favor: the emphasis on the need of scientists for each other; the emphasis on the fact that many scientists work on similar problems (the solution of any one problem being based on the solutions of many others).

All About Fish, by Carl Burger (Random House), is a fine book that suffers, unfortunately, from this series' running title. To tell "all about" fish is impossible when one has only 134 pages in which to describe the habits of 25,000 species, as well as man's relationship to them. In this impossible situation, Mr. Burger has chosen his samples wisely and well. He talks about salt- and fresh-water varieties; about strange fishes with strange habits (there are far more than we might imagine); about migratory and reef fishes; about commercial methods of catching, such as trawling; and about the methods of fishing used by primitive peoples. The line illustrations, rendered in blue, orange, and black, rather than black and white, are good.

For the student who would like to have readily available an almost limitless supply of ideas for experimentation, there are two excellent books this year, brimming with suggestions for experimental research and ranging in scope from the simple to the sophisticated. *101 Simple Experiments With Insects,* by H. Kalmus (Doubleday), is a superb reference book, filled with research ideas about almost every type of insect. This is handy because there are experiments that can be applied to the insect at hand, rather than experiments that require finding some remote, hard-to-locate species. The experiments are modern, simple, clearly stated, and most do not require elaborate equipment. Dr. Kalmus has called on the techniques of many outstanding research workers and has divided his book not into insect categories but into broad biological principles that can be demonstrated when using an insect as the experimental animal. These principles can be applied to many other species. The book presumes a good background in insect identification and knowledge of anatomy, which will limit its usefulness for younger children, but the high school student will find it a boon, indeed.

More Research Ideas for Young Scientists, by George Barr (Whittlesey House), is a more general work, dealing with chemistry, astronomy, electricity, weather, the human body, sound, light, water, and the like. The experiments are clearly outlined and supplemented by diagrams that are self-explanatory; in fact, these are so explicit that one might not even need to read the text to design the experiment. Some of the experiments are simple enough to be used in kindergarten—one of my preschool friends was amazed to find that her pennies shone after she placed them in lemon juice and salt—while others show the older student how to make an electric generator, how to test for color blindness, how to set up a working model of the solar system. There are ideas in this book to fill the needs of children from 6 to 16; there are ideas to fill science fairs for years to come.

If the two books, *Ducks, Geese, and Swans,* by Herbert Wong, and *Western Butterflies,* by Arthur Smith, are good samples of the works that Sunset Junior Books (Lane Book Co.) plans to produce, we have a significant new contributor to the field. Both are beautifully illustrated, clearly and well written, and filled with the kind of information a young naturalist wants—in the case of butterflies, where to find specimens, which specimens live in which ecological areas, and how to collect them. The illustrations are good enough to be used as a key to identification. Both books are concerned with the western representatives of these animals, but there is enough similarity to make them useful to children in the East. Considering the general beauty of the books, the attractiveness of the covers, the fine illustrations of the animals, and excellence of the prose, I feel that a child not yet a naturalist might well become one with such assistance. Certainly, the budding naturalist will be pleased with these additions to his collection.

Animal Clocks and Compasses, by Margaret O. Hyde (Whittlesey House), is a very different kind of natural history. It opens entirely new vistas for the child of 12 to 11. It will tell him new things about animals he may collect or observe, things he cannot learn merely from looking at and identifying the animal. For instance, many have dug fiddler crabs, but did not know that the greatest activity of the crab changes time each day—in rhythm with the tides' changes. The book contains excellent summaries of problems of fish, of bird, of insect, and of mammal migration. However, its

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most up-to-date material is on biological rhythms, on the attempts to understand how animal movements are biologically initiated. Mrs. Hyde has evidently talked with many scientists about their research. Her reporting is accurate, although she does not "hedge" sufficiently in some cases. For example, the theory that eels travel overland is not wholly confirmed as fact. Nonetheless, the author shows the serious student what a vast amount of work is still to be done, for we do not yet understand many of these relationships between organism and environment. This book will inspire observation and experimentation.

Treasures by the Millions, by Harry Edward Neal (Messner), is the sort of book one should read before visiting the Smithsonian Institution. Filled with tantalizing photographs, it relates the many adventures that took place long before that great museum's exhibits were created and the specimens placed on view. It tells how the Smithsonian acquired its name. (It seems strange that a place so clearly American was started by a grant from a British citizen, James Smithson, who never visited this country). There are many stories about the histories of the exhibits, their problems, their successes. The research, the exploration, and the men who have made the Institution great are well treated throughout. This book will create a desire to visit our national museum, and the visitor who has first read this volume should particularly enjoy his trip.

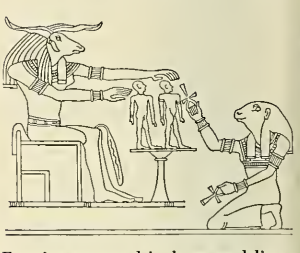
EVELYN SHAW

Anthropology

A seeming collapse of good writing, combined with advances in inexpensive color reproduction, have led to a plethora of overillustrated volumes that one hesitates to dignify with the word "book." This general truism is particularly and painfully true of the juvenile fields that anthropology covers. Parents could do worse than to use one simple yardstick in selecting from among such books for their children's library—if the work in question is teeming with pictures and your child is over ten years of age, it is probably best to turn it down, no matter how reputable the publisher may be.

This and many other factors make it difficult to write reviews without gaining the reputation of being negative or even reactionary. Certainly one has to reject far more than one would like to. The following, then, is a selected list of recent publications, which for one reason or another—not all favorable—merit attention. The favorable side of the list should be far longer, but it will take an educational revolution and a good deal of consumer resistance to achieve that.

Archeologists and What They Do, by Robert J. Braidwood (Franklin Watts), is a first-rate account of the science, and of what it takes to be a professional archeologist, by a leading professional of America's first archeological institution, the Oriental Institute of the University of Chicago. There is not a single picture in this volume, but the words, written in an informal, personal style, conjure images that teach and interest far more than most pictures can. In short, this is the best book on archeology for juvenile readers that has appeared in recent years.



Egyptian potter-god is shown modeling a man, in *The World of the Pharoahs.*

Aside from an unfortunately silly title, *The First Comers*, by Alice Marriott (Longmans, Green), is an excellent introduction to the archeology of North America. It is an informal manual of archeological techniques, as illustrated by field work in America (with emphasis upon the Southwest). The reader gains a perspective both of life in prehistoric times and in interpreting the preserved remnants of that life. There is an excellent bibliography and an outline of the various states' Antiquities Laws.

Secrets of Minos, by Alan Honour (Whittlesey House), is a biographical account of Sir Arthur Evans—who discovered, excavated, and restored the almost forgotten city of Knossos, capital of the Cretan world. Mr. Honour has caught much of the spirit of this pioneer archeologist and Sir Arthur emerges with his dignity, character, and enthusiasm still intact—a miracle in these days of two-dimensional writing. This book certainly should catch the imagination of a boy or girl who has dreams beyond the mere economic.

Ships, Shoals and Amphoras, by Suzanne de Borhegyi (Holt, Rinehart and Winston), is an informative little book on the problems and the accomplishments of Scuba-equipped, underwater archeologists. There is a rich enthusiasm in the writing that ought to attract many to this special facet of the science.

A translation from the German edition, *The World of the Pharaohs*, by Hans Baumann (Pantheon), is a lovely, gentle book. It cannot be recommended too highly. It is illustrated with first-rate line drawings and wonderful, full-page color photographs. The author tells of Egypt past and present, of the Pharaohs who created ancient Egypt's splendors and the archeologists who recovered them after centuries. It is an Egypt seen through the eyes of the Egyptian archeologist's son, Megdi, whose eager inquisitiveness leads him along a fabulous trail that should make any American child worth his salt dream of the day when he, too, can explore the many wonders along the Nile.

The Indian and the Buffalo, by Robert Hofsinde (Morrow), is a straightforward account by a native Indian who has written a number of books on Indian life. It is the study of how the bison was hunted by the Indian and how important these vast herds were, not only to Indian subsistence but to numerous culture practices. Simply written, it is informative. But it is also a pathetic book: it does not (cannot?) recount the bitter story of the murderous slaughter of the herds by the white man and the real depth of that injury to the Indian.

A story filled with fine magic is *Throw Stone, The First American Boy*, by Ted Sayles and Mary Stevens (Reilly & Lee). It transports the reader back to the time when the first people crossed the Bering Sea into the New World. It tells of their life as they drifted slowly south, seeking the game of the Ice Age. That remote world is seen primarily through the eyes of the boy, Throw Stone. The perilous events are climaxed by a battle with a mammoth that has the ring of authenticity. The authors have both authority and narrative power.

The American Indian, by Oliver La Farge (Golden Press), is a great disappointment. One opens this book, by a distinguished writer, to find his fine views buried in a garish potpourri of exuberant illustration. One can almost resurrect that scene when the publishers told Mr. La Farge that they wanted a children's version of his excellent book on Indians ". . . loaded with pictures. Hit those kids right in the eye." The undignified and certainly uninformative result is worthy neither of the author nor of the artists whose works are mushed into this rainbow heap. An apology, addressed to each Indian tribe and each Indian-respecting child in North America, should be included in every copy.

WALTER FAIRSERVIS, JR.

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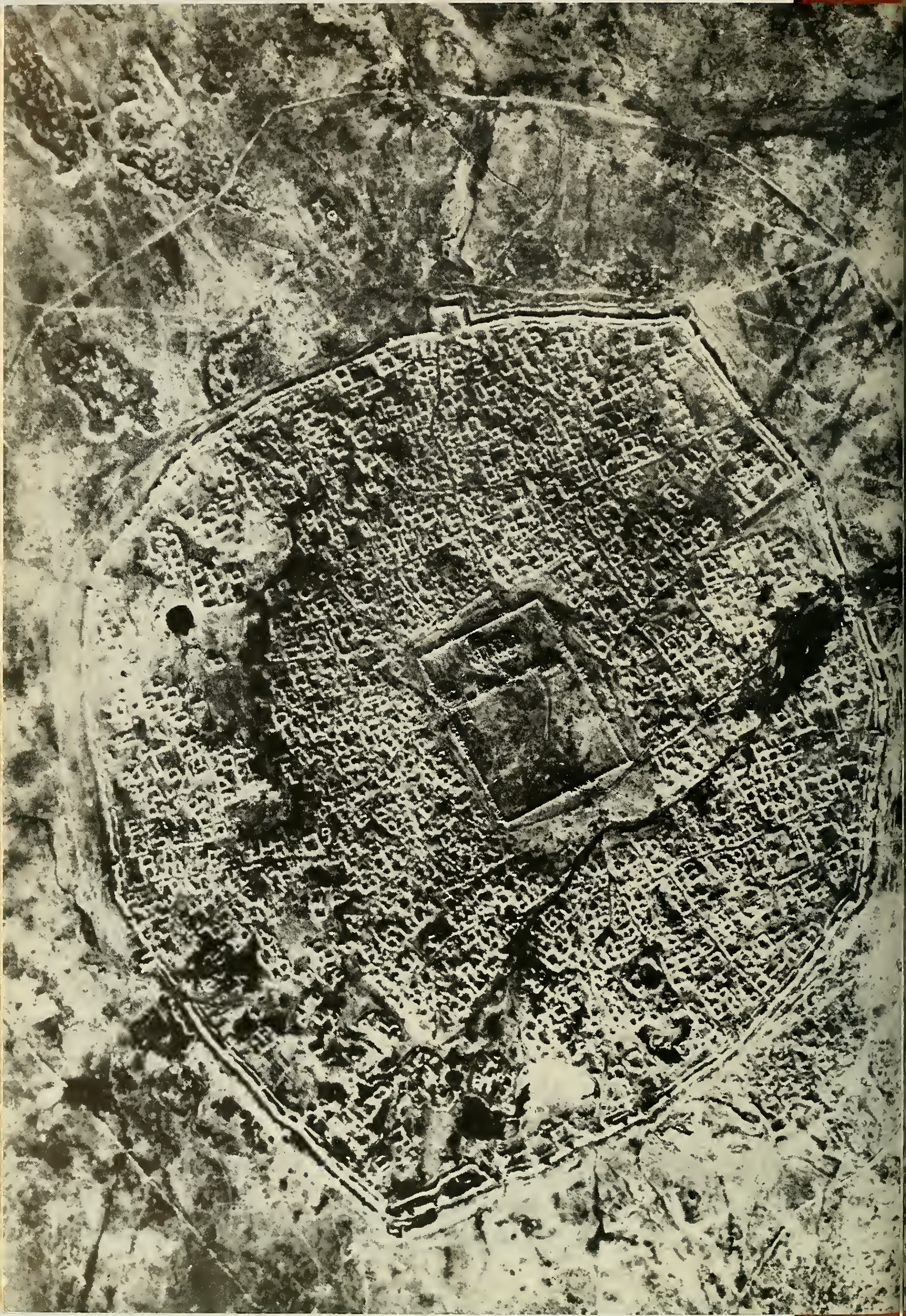


Aerial Aid to Archeology

Cameras, aloft, help to guide the spade

By David Linton

In the basement of the Turkish Army Geodetic Laboratory, Captain Ilham Durupinar was looking at photographs with the aid of a strange machine. Knobs and cranks projected from it, lights glowed in its interior. Captain Durupinar peered inside it through a pair of eyepieces hooded by blinders. It was a dull, routine sort of job—filling the gaps in the map of Turkey. For this purpose, the most inaccessible parts of the country had been photographed from the air, and it was the captain's job to measure distances and draw contours with the machine—a stereoplotter—and then transfer them to maps.

One of these inaccessible areas lies at the northeast corner of Turkey, in a pocket between Soviet Armenia and Iran. Here, rising 16,945 feet, is Mount Ararat where, claims biblical tradition, Noah's Ark ran aground after the great flood. As the captain studied picture after picture of the bleak, rocky terrain, he suddenly stopped and looked again: on a mountainside 7,000 feet above sea level and 200 miles from the nearest sea was an object shaped something like a ship. It was 500 feet long (close to the 300 cubits specified in Genesis) and its smooth, symmetrical outline formed a marked contrast to the surrounding slopes and ravines.

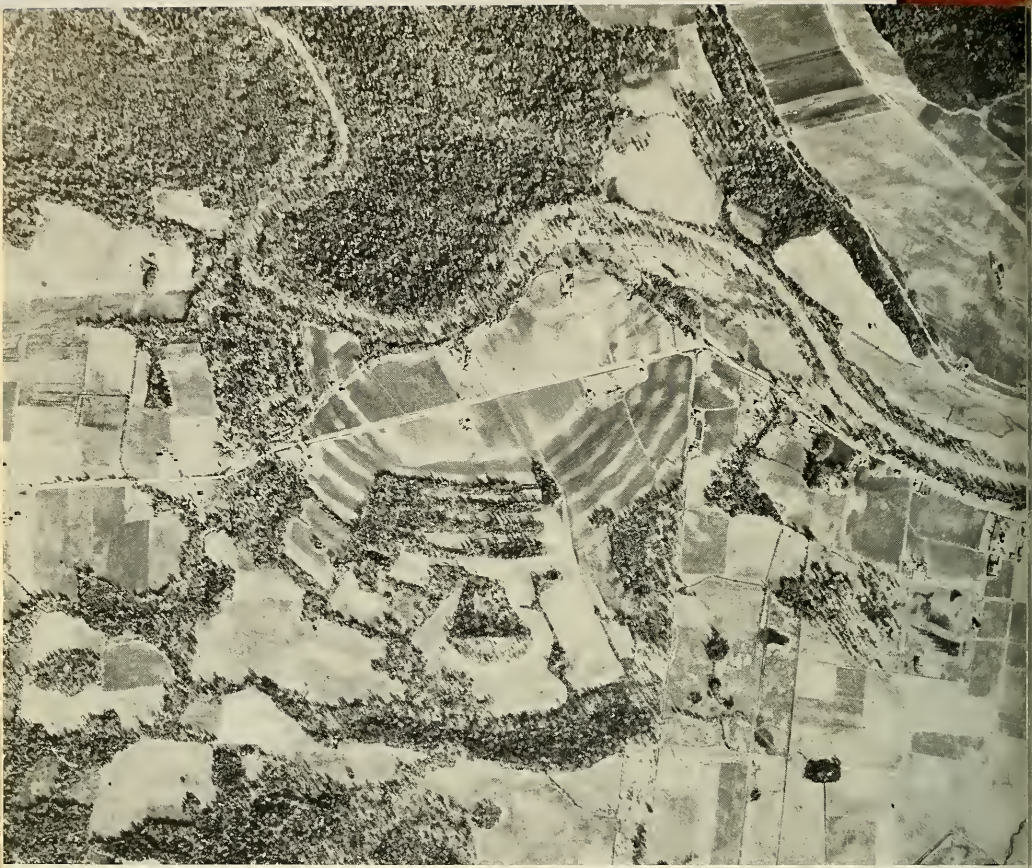
Now, this "find" has not yet been identified. A brief visit by a group, including American scientists, established that the steep-sided object has a grassy mound in its center. Small fragments of wood were found in the earth composing its rim. But any conclusions as to the origin of the ship-shaped mound will have to wait until a full-scale expedition is sent out to excavate it. In several respects, though, this episode typifies the new approaches to archeology that are made possible by developments in modern science.

The twentieth century has added a number of new weapons to the archeologists' traditional arsenal of picks, shovels, screens, trowels, and brushes. Perhaps the *second* most important of these new instruments is carbon-14 dating, the technique that earned its inventor, Willard F. Libby, the Nobel Prize. The other great twentieth-century contribution to archeology is likely to prove even more important than carbon-14 dating because of its range of applications. This is aerial photography. It figures not only in the chance discovery of possible archeological sites, as in the episode described above, but also in reconnaissance that can tell archeologists where *not* to look—not to mention its more obvious contribution in orienting and mapping known sites.

Aerial archeology—if such it may be called—has no single inventor, but military reconnaissance and civil engineering are its godparents. Today, largely because of aerial photography, there is an enormous backlog of known or suspected archeological sites waiting to be investigated when funds and staff are available.

The discovery phase of aerial archeology relies on the fact that man has developed distinctive shapes (and in some cases distinctive sizes) for his constructions, which immediately set them apart from the works of nature. In dense jungle, for example, anything built by man will be rapidly

Now deserted, the ancient Iraqi city of Hatra flourished early in Christian Era. An aerial photograph will help to reveal such a site in its total context.



Mound at Poverty Point, Louisiana, was thought to be a natural formation until aerial photographs revealed large concentric earthworks, obscured by cultivation on ground. Excavation confirmed site as man-made, dated it 400 B.C.

obscured as soon as men stop cutting back the jungle. But in the Yucatan forests, a straight line of elevated trees, visible only from the air, still traces Maya roads that might be invisible from a few yards away on the ground. The geometric arrangement of the lines marks them as human artifacts.

The same is true of burial mounds, house sites, or the earthworks of ancient forts. When very old, such features may be so obscured by later plant growth or cultivation that their shape cannot be perceived from the ground. Often they cannot be perceived from the air, either, except at those hours of the day when the angle of the sun throws their contours into relief. Such traces of early digging and building are called shadow marks.

Another, though much rarer, type of relief trace is revealed when a light snowfall is followed by wind that blows the snow from the more exposed parts of the landscape and piles it in the sheltered spots. Slight variations in elevation stand out in aerial photographs made at such times, and distinctive forms may emerge, indicating ancient human construction.

In places where the land is occasionally flooded, either by design or accident, a similar highlighting of fine relief may occur when a few inches of water cover the lower parts of terrain while higher parts are dry. All such relief traces are particularly helpful in locating the sites of ancient walls, ditches, and watercourses, as well as the slight mounds that usually mark the sites of ancient farms.

Until fairly recent times, man did not have organized methods for getting rid of the refuse he produced. In ancient towns the by-products of human existence, which we now consign to sewage and garbage disposal systems, were simply thrown into the street, whose level accordingly rose. When it reached such a point that rain water ran from the street into houses, the floor levels of the houses were raised, too. Thus ancient cities and towns tended to increase in elevation as their occupation continued. This rise in elevation is seen in pictures taken—under proper conditions—from the air. This is also why the shovel remains the basic tool of archeology.

The most important traces left by man on the land, however, do not result from his moving the earth about but from his effect on its fertility. Such traces are called plant marks, and can be either positive (i.e., where man's disturbances have increased fertility) or negative (where they have decreased fertility).

Positive plant marks are formed where buried ditches, building sites, farmyards, stockades, garbage pits, and similar remnants of human occupation make the earth above them more fertile than the surrounding land. When covered by crops, the sites may produce plants that grow taller and greener than their neighbors. The effects last for very long periods and the affected areas are likely to be sharply marked—so much so that they can be measured precisely on aerial photographs of a region. The ditches that surrounded Neolithic settlements on the Tavoliere Plain near Foggia, Italy, have long since been filled in but, in that dry region, the extra moisture they supply to the plants growing above them makes their pattern still visible from the air after 4,000 years. Over 170 Neolithic sites have been located in this one region, which measures only a little bit more than 1,500 square miles.

One of the most remarkable contributions made by aerial photography to archeology is in the discovery of the Etruscan city of Spina. It was built about 500 B.C. in the swampy delta of the river Po—not far from modern Venice. Spina is referred to in classical literature, but many archeologists disputed its site or actual existence until its ruins were discovered a few years ago through plant marks. Like Venice, Spina had canals for streets, and the whole pattern of the city was revealed by aerial photographs showing the positive effects of the ancient watercourses on the fertility of today's plantings.

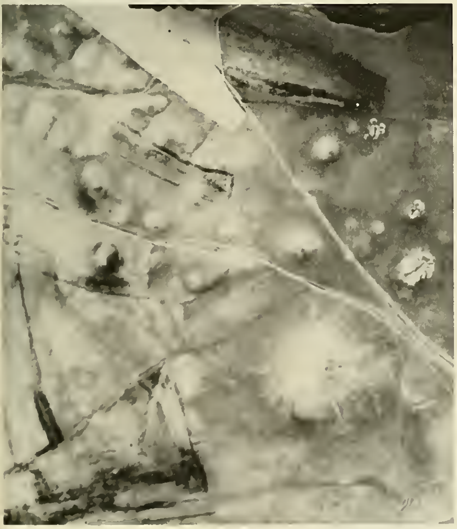
Negative effects on fertility are also visible from the air: buried stone walls and streets may interfere with the root systems of plants growing over them, so that those plants do not grow as tall as others in the same field. The entire plan of the Roman town of Caistor in Norfolk, England, down to the sites of the forum, temples, and baths, was revealed through such negative plant marks in a RAF photograph taken in 1929.

Dry weather, particularly if it lasts throughout the growing season, generally favors the archeologist. In dry years, plants are forced to extend their roots farther downward to get water; in those years the encouraging or inhibiting effects of underground structures are most likely to be seen in the growth of plants on the surface.

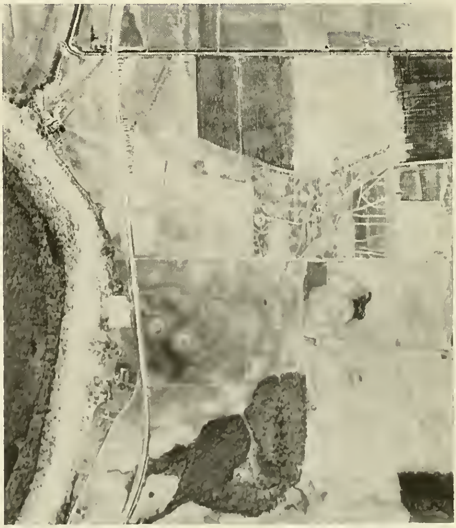
In addition to these basic factors influencing plant marks, there are many variations that provide archeological clues to anyone trained to read aerial photographs. There are a few ancient sites, for instance, marked by plants of completely different species from those nearby. In southwestern Greenland, the Norse colonists, who came from Iceland in A.D. 985 and thereafter, introduced certain nonindigenous plants (whether intentionally or accidentally we do not know). Although the last of the colonists disappeared about A.D. 1500, the sites of their farms are clearly visible on that treeless terrain. The traces can be seen from the deck of a boat on a fiord, but aerial photography gives an even better over-all impression of the patterns on the landscape.

In some places man has left his mark on the land by altering the chemical composition of the soil, and this, like the difference in moisture content, will influence the growth of plants above archeological remains. Certain chemicals in the soil may encourage some plants and discourage others, or they may produce differences in color, as well as luxuriance, even where the plants are all the same variety. The soil over ancient cities is rich in phosphates because of the high proportion of organic material. Phosphates make good fertilizer, and the plant growth is heavier above such sites if moisture is sufficient. (The latter-day neighbors of many ancient cities in the Near East have mined the city mounds to fertilize their crops.)

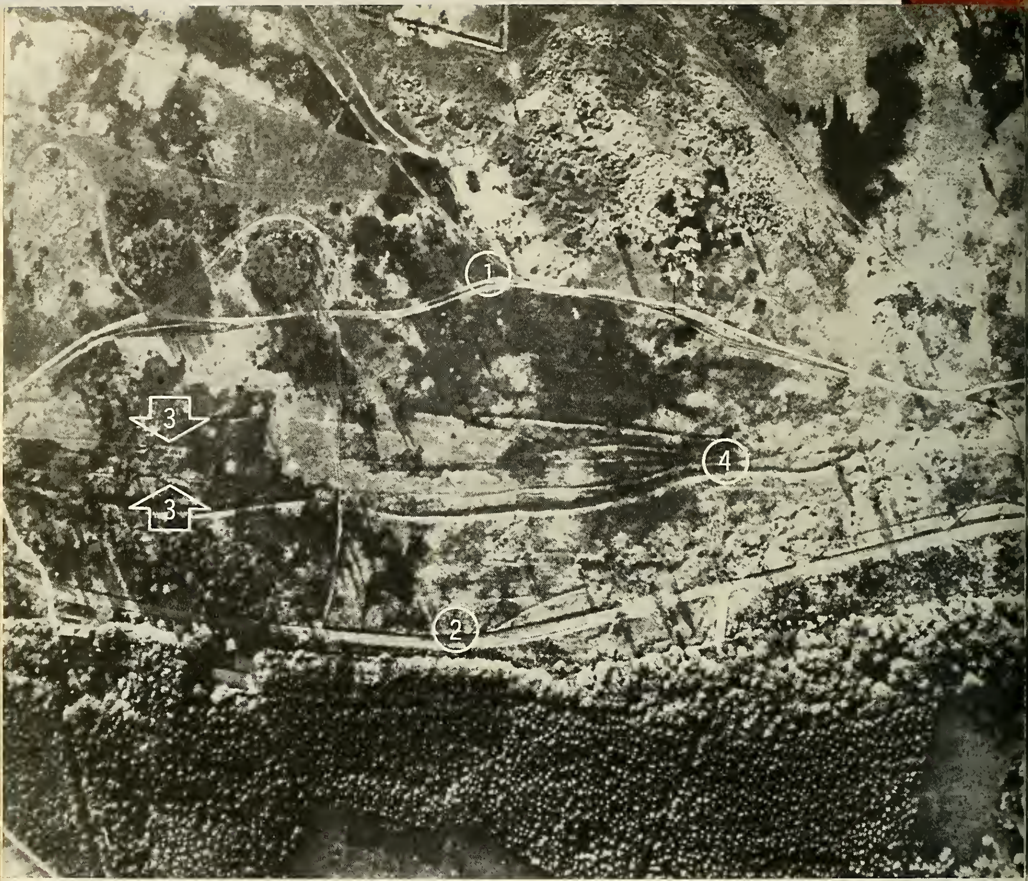
Sometimes modern planting of a uniform crop will bring out plant



Stony burial mounds were revealed clearly by soil marks, aiding in excavation of site of ancient Gordion, in Turkey.



Indian mounds (center) were on island before Ohio River changed its course. Finds confirmed dating of river's shift.



Centuries of history are revealed by aerial photograph, *above,* of Ashdown Forest, England. Between modern roads (1 and 2), a straight Roman road (3)—marked by parallel ditches exactly 62 feet apart—was found. Hollow way (4),

Roman road (center) survives as plant mark even where land is plowed over.

marks where none was visible in the natural ground cover. A rather rare effect was seen when Mill Heath, in Suffolk, England, was planted in 1947. The crop did not do well except in one spot, where a rich growth revealed the outlines of a Roman building. Apparently the lime in the mortar of the long-buried walls had neutralized the prevailing acidity of the soil.

Sometimes the soil itself reveals traces of ancient construction, even where there is no vegetation or where the ground cover has been plowed under. Ditches that penetrated the subsoil will show up in aerial photographs as lines of darker color because of their higher moisture content.

meandering across it, was identified as medieval trail, worn by pack horses.

Rows of stones from ancient terracing, property divisions, and roads tend to show up as lighter lines. Even where old stone walls have been leveled and plowed under, the stones that comprised them have seldom been carted away. Surface erosion reveals the bands of extra-stony soil: the geometric pattern marks them as man-made.

Soil erosion patterns on a very large scale—discovered by chance—have even changed our understanding of Italian history. The poverty and infertility of southern Italy used to be attributed to Roman or early medieval farming methods. Examination of photographs taken during World War II, however, showed that the cause was the introduction of Spanish sheep-breeding methods after A.D. 1300.

Soil marks often reveal ancient systems of land division. The Romans applied their typically disciplined approach to the practice of surveying. Their fields were laid out on a grid plan very similar to the system of sections and townships that still stamps any air view of America's prairie states. The basic Roman section was a square, 20 *acta* (2,330 feet) on a side. The sections were separated by roads, and every fifth road was a main highway, wider than the others. Sections were divided into smaller units, all rectangular, down to the *jugerum*, equal to about ⅝ of an acre—the area that one man with two oxen could supposedly plow in a day.

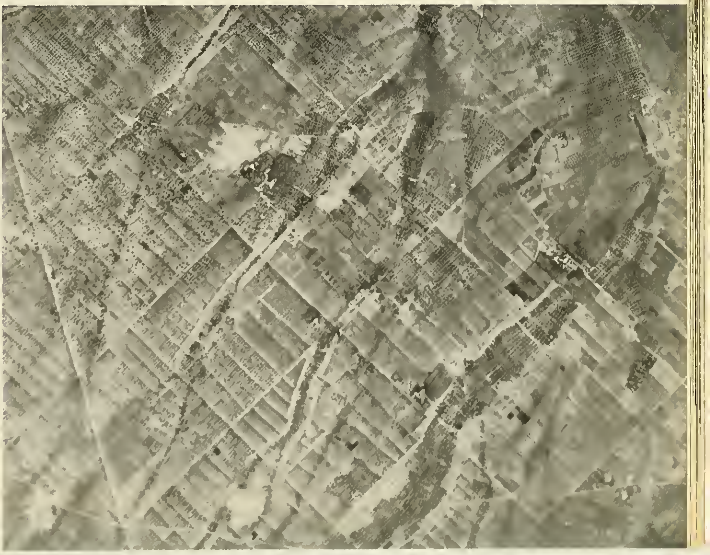
The fields laid out according to this system—known as centuriation—have survived in many parts of the Mediterranean world, for the Romans persisted in imposing this rather rigid plan on their colonies. Many of these fields can be identified from the ground, but it is only with aerial photography that the characteristic surveying plan is clearly grasped.

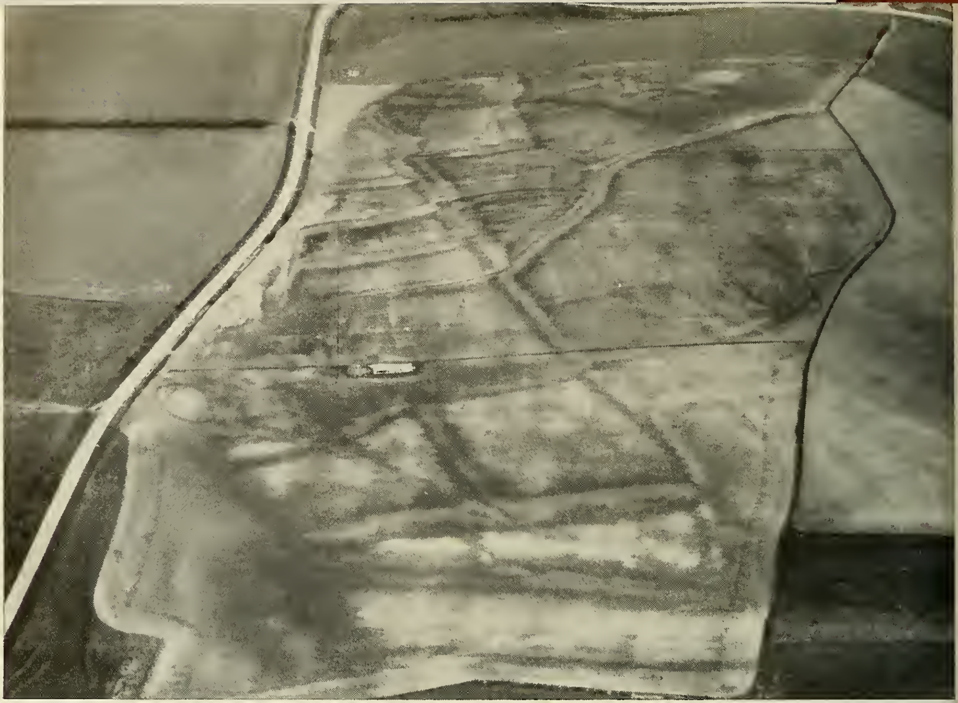
These Roman fields point up several principles of aerial archeology. Man's patterns are revealed by soil marks in characteristic shapes and sizes; they have endured for centuries either because their traces remained in spite of later cultivation, or because they were incorporated into the latter-day landscape; and they often go unrecognized from the ground because they are too big to be seen at close range.

Large archeological sites may pass unnoticed for years because an observer on the ground cannot see their distinctive shapes. One of the most important finds in the United States in recent years is a large mound, some 70 feet high, at Poverty Point, Louisiana. The mound had long been known and had always been thought to be of natural origin. But in 1952 Dr. James A. Ford of The American Museum discovered from aerial photographs what had never been observed: the mound was surrounded by a series of earthworks including six concentric banks, the largest of which was almost a mile in diameter. Small quantities of stone implements had been found here years before, but the extent of the site had not been suspected. Subsequent excavation has established that the mound, like the earthworks surrounding it, was man-made, dating from about 400 B.C.

A particular class of archeological sites includes those now lying under water. Because of its reflecting surface, water is more transparent from overhead than from any other angle. The remains of submerged cities and seaports in shallow water can often be mapped with great accuracy from a single aerial photo. And from suitable pairs of overlapping photos it is possible to measure depths in the same

Characteristic rigid field plan marks Tunisian town as former Roman colony.





Differential fertility, accentuated by cultivating land, is visible on aerial photograph of a Celtic field system in England. Dark lines are due to subsoil's having been turned over originally for ditches; light lines are the old ridges.

way that the elevation of land is determined in topographic map-making.

The present state of the art limits aerial photography of underwater sites to depths of about 60 feet, even with optimum visibility. (The sun should strike the surface at an angle of slightly under 45° to minimize reflection.) But archeology is bound to profit from the research in underwater mapping now being carried on by the U.S. Coast and Geodetic Survey, and refined techniques will certainly be introduced. Even now, the camera can see considerably more than the eye because the former's sensitivity can be controlled. Film and filter combinations can be chosen for maximum sensitivity to those wave lengths of light that penetrate water best. Contrast can be controlled by choice of film and development. A research unit of the British Army found that details in shallow water (less than 20 feet) were recorded best with a red filter, while those in 20 to 50 feet of water were best seen on a panchromatic film exposed through a green filter. But there has been little study of special photographic techniques for archeological use.

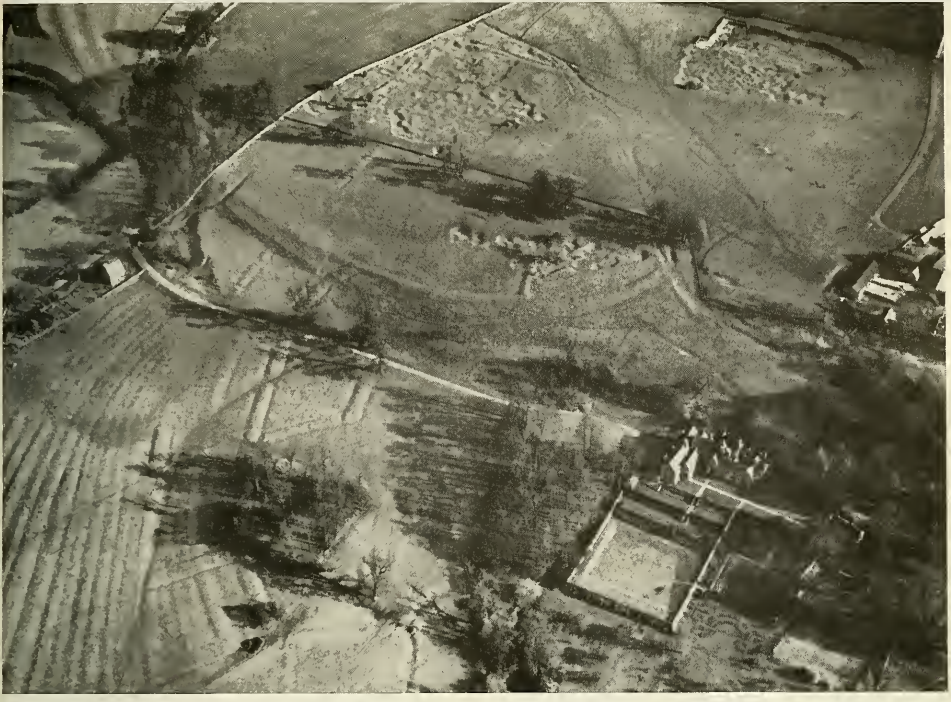
Some submerged remains, however, have already been revealed by aerial archeology. The most luxurious of seaside resorts for ancient Romans was Baiae, near modern Naples. Today it is under 30 feet of water, but its streets, buildings, and open squares are recorded on film. It would take months for divers to come up with an equal amount of information, and it is unlikely that they could ever make as accurate a map, since terrestrial surveying techniques are hard to use under water and depths are too small for oceanographic apparatus.

With the aid of aerial photography, the archeologist may find valuable clues even where there is no sign of human handiwork. In territory where cave dwellers lived, pictures can reveal the mountains in which caves are most apt to be located. Where shore lines have changed, photography can locate ancient beaches on which coastal peoples must have lived, and where their campsites and shell middens are likely to be found ("First Traces of Man in the Arctic," Natural History, November, 1960). In arid lands, certain surface features may point to sites of ancient springs, now dry. Springs have always been the focus of desert life, and they are the first places to look for remains. Aerial reconnaissance is particularly important over desert and other barren land because it can tell us where *not* to look, by eliminating the areas that were unsuitable for habitation.

A well-known science photographer, whose camera column is a feature in this magazine's pages, **Mr. Linton** has long been interested in problems and techniques of aerial photography.

It is in the study of surface features of the land that archeology has been able to repay a small part of its debt to geology. Geology has traditionally provided the framework for dating archeological sites; but recently it has been possible to date river courses, beaches, and other surface features by mapping the archeological sites on them and dating the sites by the carbon-14 or other methods.

After a site is discovered—either from the air or on the ground—a field investigation is necessary to establish its history. Here, too, aerial photography can be extremely useful. It can



Shadow marks cast by a low sun reveal old building sites and earthworks near Gloucester, England. When optimum conditions such as angled lighting are utilized, an oblique photo like this frequently can reveal more than a vertical.

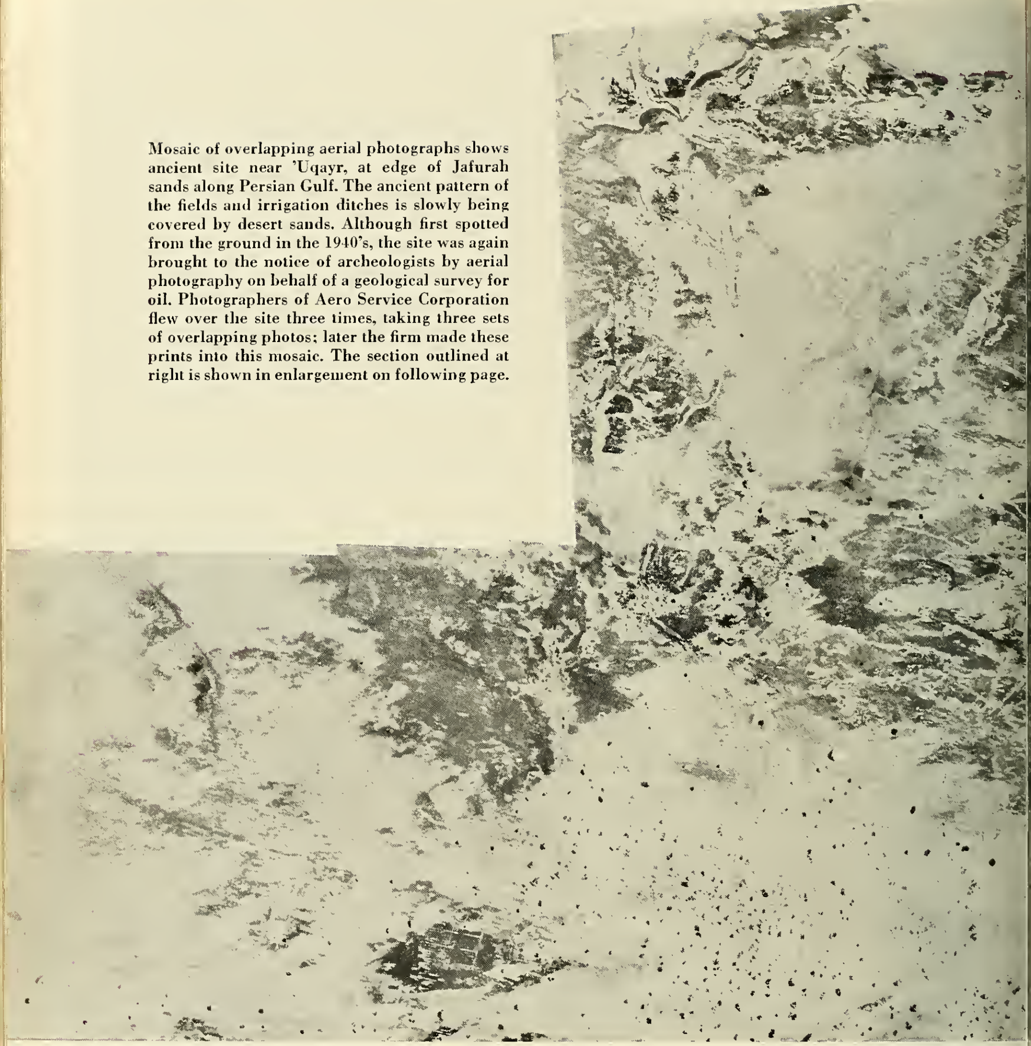
elucidate the history of the surrounding terrain, showing where rivers have changed courses, where lakes have dried up or dry land has been flooded, or how erosion and landslides have changed the shape of the land. It can determine the geographical orientation of streets and buildings—a point of considerable interest, because some ancient peoples built their temples to face certain points in the heavens and this knowledge helps us to reconstruct their system of astronomy. Aerial photography can also give us precise measurements of the site itself, including the width of streets, thickness of walls, and gauge of cart tracks, as well as various indexes from which it is possible to estimate the population of a long-dead town.

The techniques by which aerial photographs are made to yield such detailed information have been refined over the years. Consider the matter of determining distances. Most of the aerial photographs made today will yield precise measurements of vertical as well as horizontal dimensions. These measurements are made in the same way that the human mind "sees" in three dimensions: by comparing two (or more) pictures of the same thing taken from different viewpoints. A human observer depends on two "pictures" recorded by eyes only 2¼ inches apart. If the human looks at a landscape 2,000 feet below, the difference between the image seen by one eye and that seen by the other is insignificant. Photographs, however, are taken at intervals of hundreds of feet and the relief on them, when paired, is proportionally greater. Although any pair of pictures can be used, some will yield more information than others. To appreciate this, it is necessary to understand the basic types of aerial photographs, classed as either "oblique" or "vertical."

Oblique photographs are those taken at an angle—*not* straight down. They are often very useful in the discovery phase of archeological research because they show some kinds of details that do not show up as well on vertical photos. But there is an infinite number of possible viewpoints for obliques of a site and only one may be useful. Furthermore, that one may be useful only at a certain season or time of day. While it is possible to take horizontal and vertical measurements from pairs of oblique photos the process is difficult. Oblique photos, therefore, are most useful for reconnaissance or for recording sites that have already been discovered.

Vertical photographs are taken straight down (or as close to straight down as flying conditions permit). Correction can be made later for tilt of the plane, wind drift, and variations in altitude. The vertical photograph is like a map—in fact, most modern maps are based on verticals—and is extremely useful for making precise measurements. Most verticals are now made by automatic equipment that takes the pictures at fixed intervals as the plane flies along a predetermined course. Since these pictures overlap, there are always at least two views of every point on the ground.

The pairs of pictures are useful for reconnaissance as well as for measurement, because the vertical relief seen when they are studied is considerably exaggerated. Overlapping verticals—or stereo pairs—are used for making topographical maps, for prospecting, for planning construction projects, Mosaic of overlapping aerial photographs shows ancient site near 'Uqayr, at edge of Jafurah sands along Persian Gulf. The ancient pattern of the fields and irrigation ditches is slowly being covered by desert sands. Although first spotted from the ground in the 1940's, the site was again brought to the notice of archeologists by aerial photography on behalf of a geological survey for oil. Photographers of Aero Service Corporation flew over the site three times, taking three sets of overlapping photos; later the firm made these prints into this mosaic. The section outlined at right is shown in enlargement on following page.

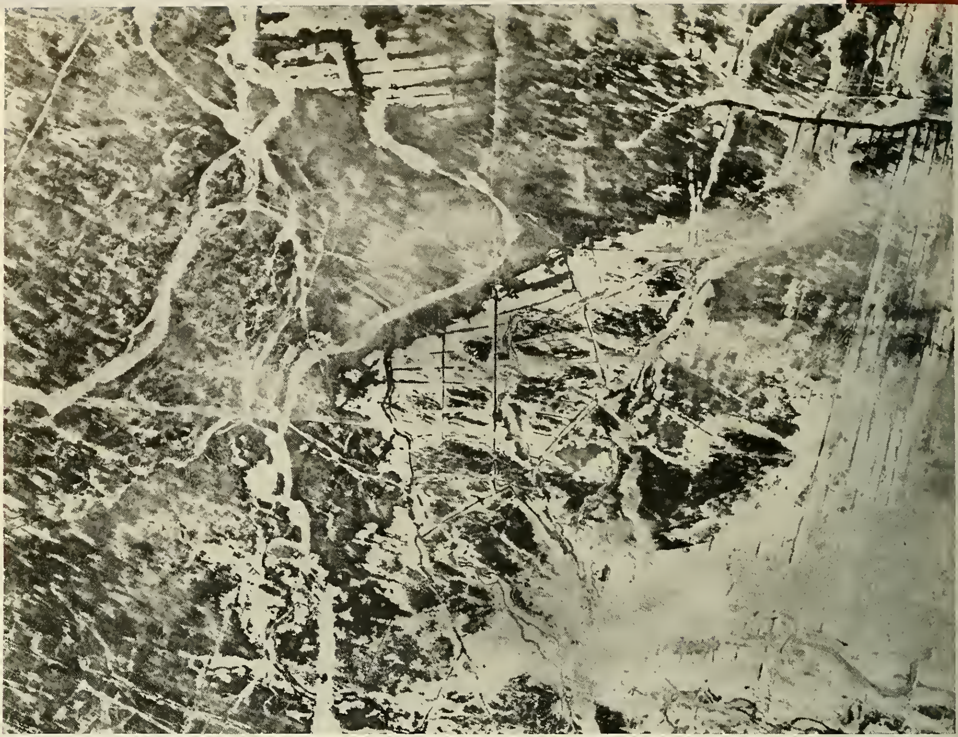


and even for assessing taxes. The majority of aerial photographs now available are of this type.

The main problem of vertical photography, and the factor setting the limits of its accuracy, is ground control. Ground control involves relating the photograph to known points on the ground, and it is through ground control that the photogrammetrist finds out what corrections are needed for the tilt of the plane, wind drift, and variations in altitude and speed. Ground control is not so much of a problem in places that have been extensively surveyed and where there are established bench marks—geographical reference points marked on the ground—whose exact positions have been determined. Even so, considerable groundwork by surveying parties may be necessary to relate bench marks to points that can b identified in photographs.

In unsurveyed territory, and especially where there are few permanen landmarks, ground control can b much more of a problem than the photography it is intended to control Prospecting and mapping companie have had to send teams through jungl and desert, and to land them by helicopter on mountain tops to establis

ground control for aerial surveys. In recent years, electronic devices have dramatically reduced the number of ground control points that must be established. SHORAN, for example, is the abbreviation for a short-range radio navigation system, part of which is carried aboard an airplane and the rest contained in small, automatic ground stations that can be moved from one location to another. The posi-



Detail of Arabian site, from previous page, shows unusual example of reverse relief: earth in old irrigation ditches was compacted and forms ridges between softer fields, eroded by desert winds. Now, however, sand is drifting over entire site.

tion of the plane in relation to several SHORAN stations on the ground can be automatically determined and recorded at the instant a photograph is taken. The entire Canadian Arctic was mapped using this control from 1952 to 1958, although the only previous survey in many places had been made with dog sled and sketch pad.

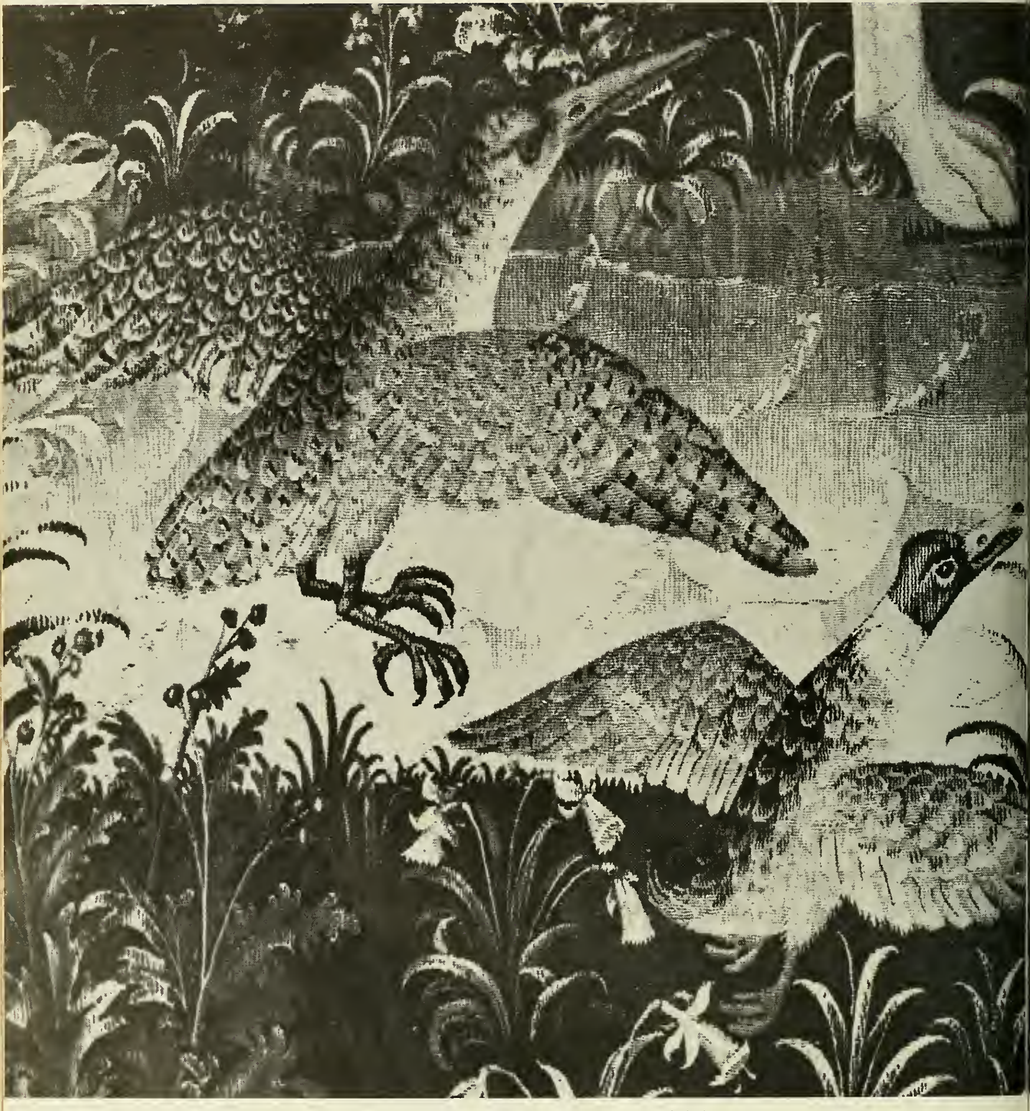
The photogrammetrist's dream is a ground control system that would require no ground stations at all. The closest approach to this now operating is Doppler radar. With this system, radar signals are sent out from the plane in four directions and "bounced" back by the ground. The difference in frequency between the signals sent and the echoes received reveals whether the plane is moving toward the point of echo or away from it, and at what speed. The time it takes for the echo to come back reveals the distance from the plane to the echo point. The computations required to make instantaneous use of all these data are made by a small computer. A certain number of known ground control points is still required with this method, but the number is greatly reduced.

Very little aerial photography is carried out originally for archeological purposes. (The current survey of the area to be inundated by the Aswan Dam is a rare exception.) Usually the archeologist uses photographs taken for some different purpose—mineral-prospecting, map-making, or road-building are typical examples. One of the great advantages of working with aerial photographs is the sheer number available. Over half of the earth's land area has been photographed at least once, and some countries (England and Canada, for example) have been systematically photographed in their entirety. Oil companies, highway and waterway authorities, flood control and soil conservation agencies, and even lumber and power companies have extensive files of aerial photographs generally available to the archeologist. These supplement the files of government mapping and geological agencies. The Poverty Point find is a good example: it resulted from a study of the survey photographs of the Mississippi River Commission.

Not all existing air photos are helpful, of course. Many are on too small a scale, taken at the wrong time of year for plant marks, the wrong time of day for shadow marks, or taken by methods less helpful for archeology than for their original purpose. But since no archeologist has ever looked at most of these photographs, they should not be dismissed lightly.

No practicable amount of study on the ground can encompass the sheer size and quantity of information that aerial photographs can record. A single picture can give a comprehensive view of an ancient community—its forms of agriculture, land division, structures, tombs, canals, roads, fortifications—and its relationship to other communities. In short, aerial archeology brings us as close as we are likely to come to seeing the way of life of an ancient people as a functioning entity.

Ship-shaped form in the rugged terrain near Mt. Ararat, *right*, was discovered accidentally when Turkish Army map makers were working over air photos.



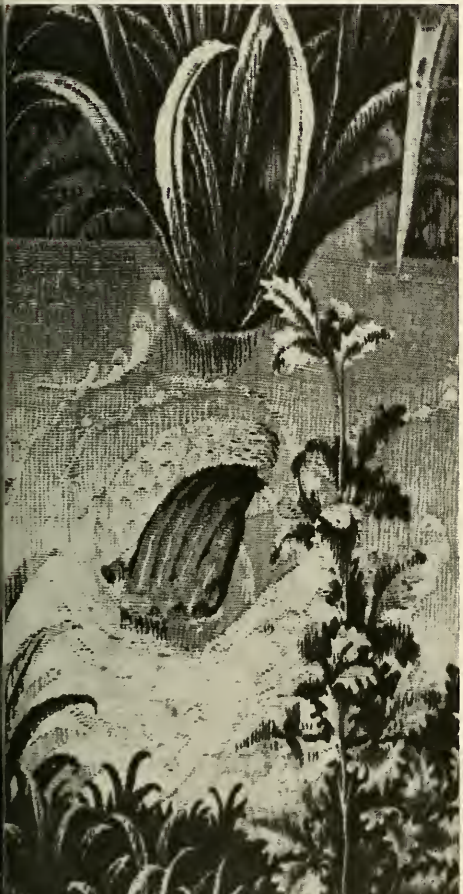
Rising from a clump of yellow iris at left is a woodcock, and a mallard also flies from stream edge. At right can be seen the tail of some diving duck.

Of Birds and a Legend

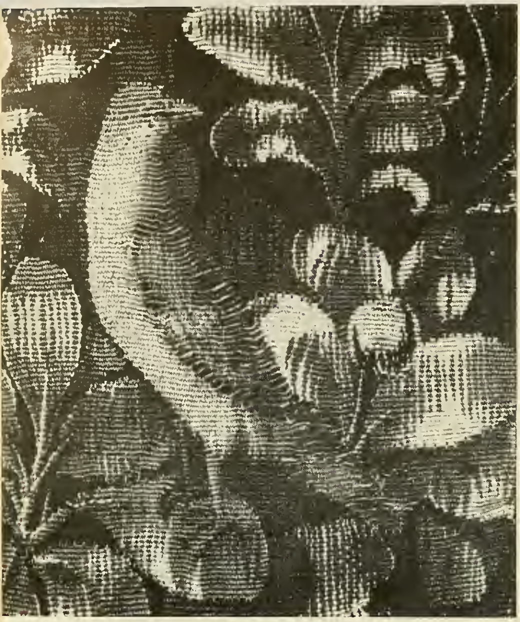
TRUTH AND MYTH ARE WOVEN IN TAPESTRIES

In the fourteenth and fifteenth centuries, an ancient art became a highly organized industry. During that period, under the patronage of kings and dukes of France and Flanders, tapestry making reached a peak of perfection never before dreamed of. Works of hitherto unimagined magnificence were loomed to decorate and warm the drafty castles of the aristocracy, to beautify churches, and to lend distinction to the homes of wealthy tradesmen. The most important centers of the art were ateliers in Paris, Arras, and Tournai.

Tapestry making is one of man's most ancient crafts, and its very origin has been lost on the threshold of the historic era. Basically, the technique is a simple one. The



Small frog, nearly invisible among the welter of flowers in the seventh tapestry, is the only amphibian in the hangings.



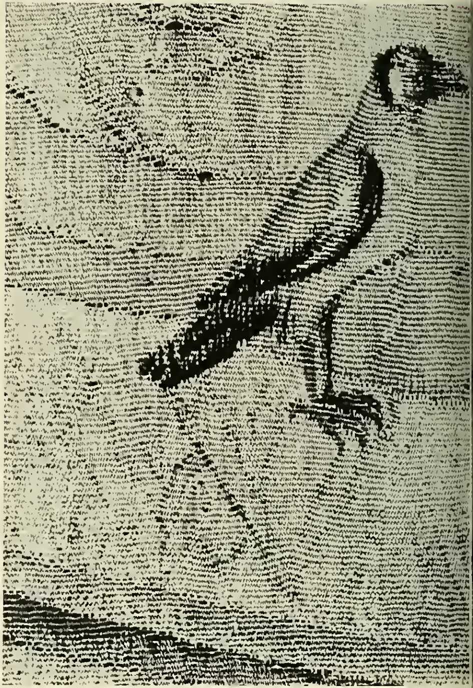
This may be a nightingale, common in Flanders. Certainly it is a small bird, as it is perched on a leaf instead of on a twig.

warp threads, which lie parallel to each other, are held taut in the looms. Weft threads, which form the pattern, are woven in and out of the warps, and are then beaten down so that they completely cover the warps. The latter then appear only as ribs in the finished textile. In the early tapestries, the principal material was wool, but silk and metal threads often enriched the design.

TRADITIONALLY, it has been said that weave in tapestries is a more significant criterion of its worth than is the design— that no matter what the pattern, it is the workmanship that identifies it as of greater or lesser artistic value. To this theory, however, the tapestries of the Middle Ages give the lie, for the brilliant designs are themselves typical of this zenith of an art form. Here both qualities are combined with an accurate mirroring of the people of the time and the world in which they moved in a manner that perhaps has never been equaled in any other medium. Of all such medieval artistry, perhaps the most magnificent are the so-called unicorn tapestries now in The Cloisters, Fort Tryon Park, New York City.

The unicorn tapestries may have been made at Tournai, a Flemish city that was nearly as well known as Arras, whose name is still synonymous with the art. Early Gothic tapestry patterns had leaned heavily on outline drawings to achieve their effects. With the late Gothic came an increased awareness of the natural world, and thus an increased realism that was reflected in the treatment of tapestry subject matter. The woven flowers, for the most part, were those that really grew somewhere in Flanders or France. People's faces were often portraits of patrons. Dwelling places were shown in three dimensions. Animals were usually representations of living beasts.

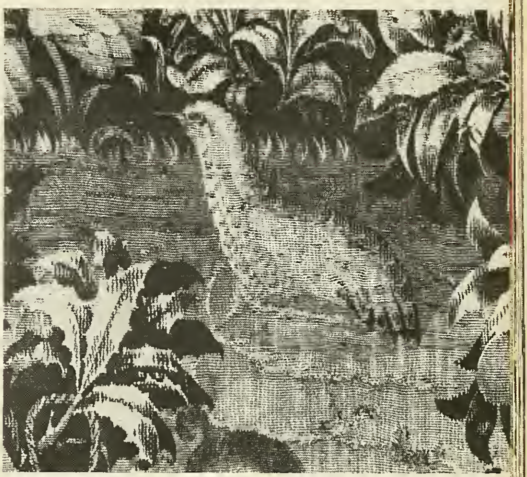
The unicorn group includes six full tapestries, each one of which covers about 150 square feet, and a small fragment of a sev-



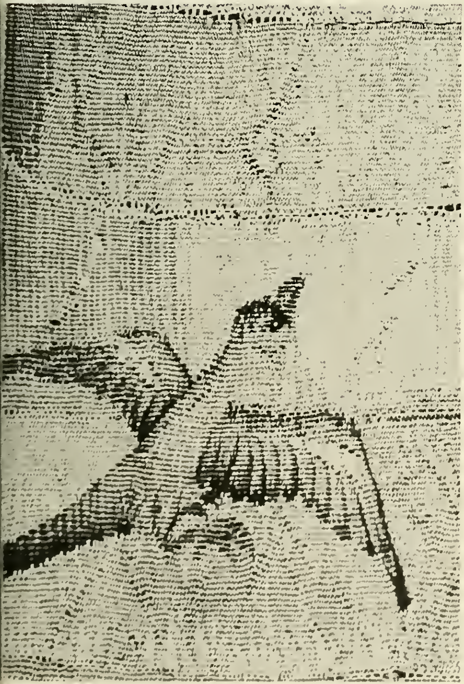
At left is adult, at right young goldfinch. This colorful bird, symbolizing Resurrection and the soul, was popular in period's art.

enth. Their history is still somewhat obscure. It seems certain, however, that five of them were made for Anne of Brittany on the occasion of her marriage to Louis XII of France on January 8, 1499.

The other two in the series have been dated about fifteen years later, when Anne's daughter was married to Francis I. Actually, they may have been made contemporaneously in different workshops. Francis was the godson of François de la Rochefoucauld, in whose family home at Verteuil, in southwest France, the tapestries hung for many years. They suffered innumerable vicissitudes, and changed hands at least once—there is even a story that, during the French Revolution, they were used to keep potatoes from freezing. Eventually, they were reacquired by a Rochefoucauld, and hung at Verteuil until John D. Rockefeller, Jr. purchased them in the early 1920's. In 1937 he presented them to The Cloisters, where they have hung ever since.



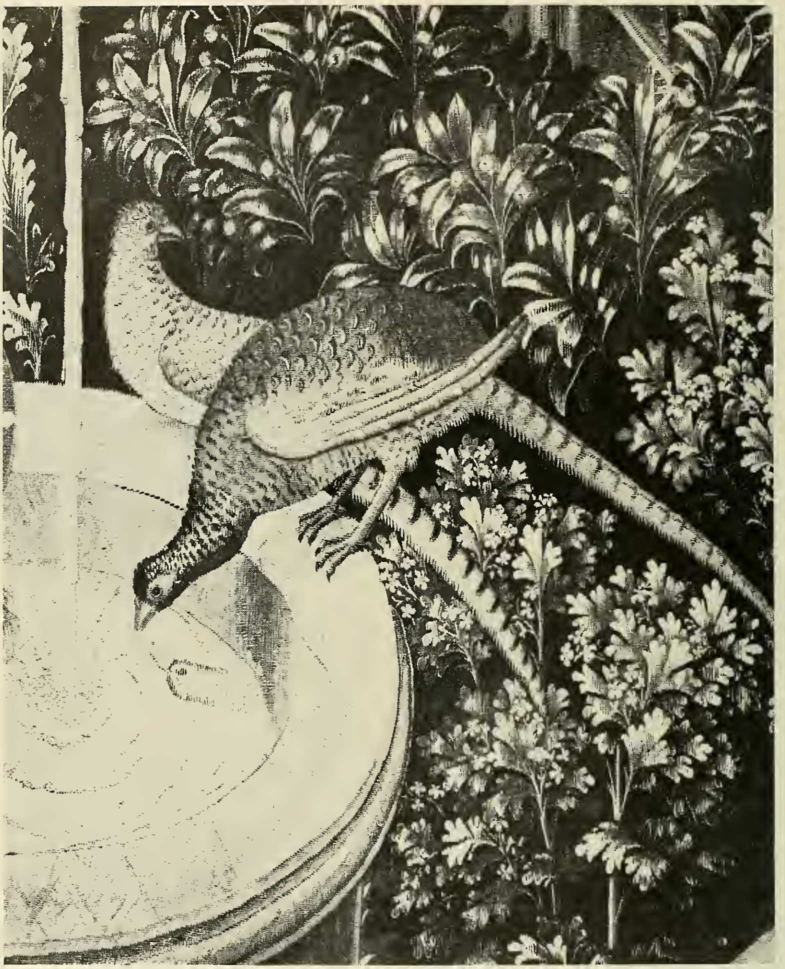
The rusty red breast suggests that this is a little bittern, although that wader's back is usually brown in color instead of gray.



A spot of red on the plumage of any small bird connected it with the theme of martyrdom and sacrifice as exemplified by Christ.

The tapestries tell of the hunting of the unicorn, a beast so virtuous and beautiful that, according to one belief, only a single animal inhabited the earth at one time. The unicorn legend dates from pre-Christian times, when such one-horned animals were thought to possess unlimited power. Gradually this belief worked its way into Christian myth. From the third century A.D. to the Reformation, the animal was a symbol of Christ. In the Middle Ages it was believed that a unicorn could be caught only by a virgin. If she approached the fleet, ferocious animal, it became suddenly tame, put its head in her lap, and was easily caught by a huntsman. In Christian allegory, the virgin was Mary, and so Christ renounced the characteristics of God in the interest of mankind. During the age of chivalry, the story of the hunt was used to dramatize courtly love.

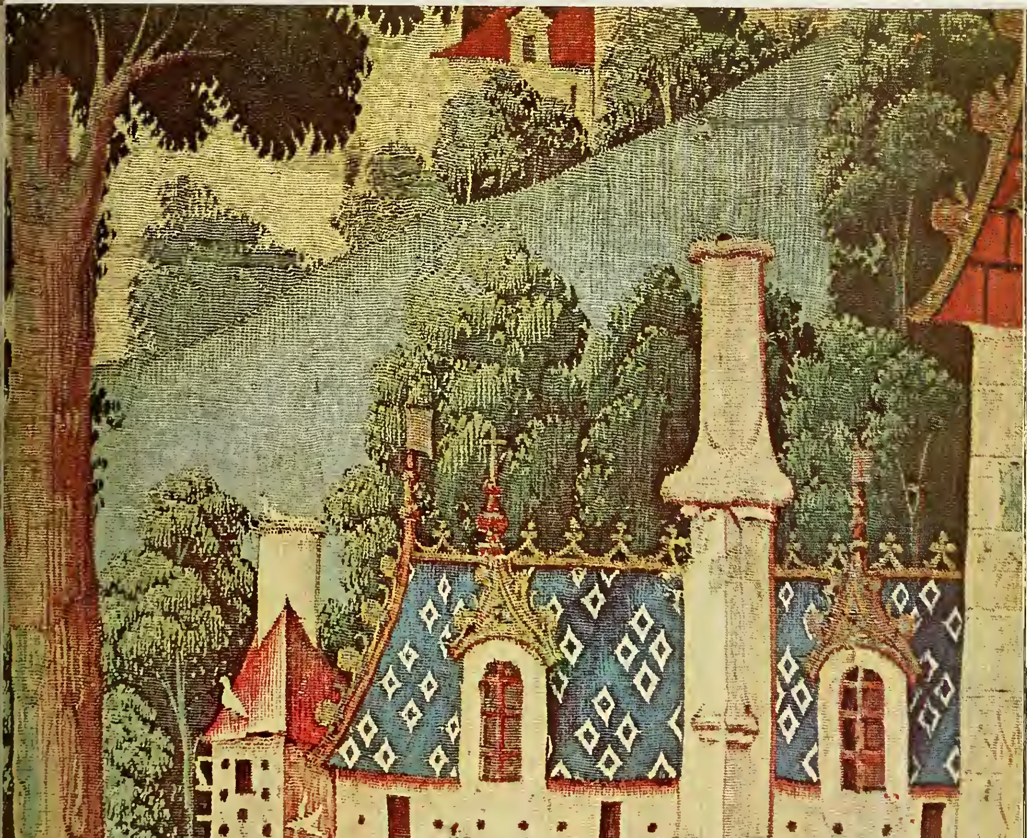
Interestingly, the unicorn is the only fabulous beast that managed to leap the gulf between the ancient bestiaries and the modern



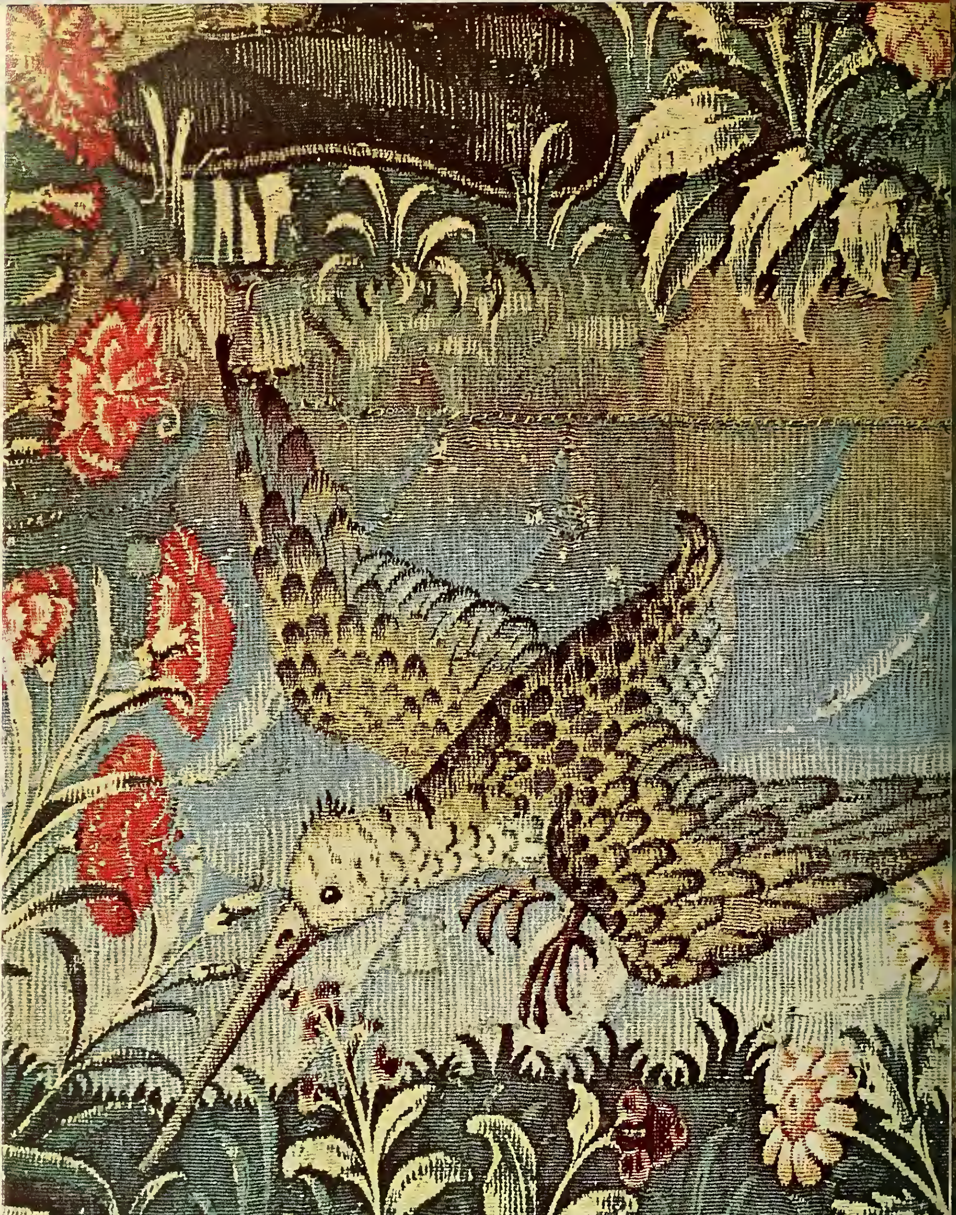
These pheasants, surrounded by cherries and flowering hawthorn, exemplify the rich details of these tapestries. Notice reflection of the bird in the water.

mind. Griffins, dragons, and their like were left behind in the mists of legend, but the unicorn persisted, perhaps aided in its survival by the religious stature given it during the age of faith. Even during the Renaissance, with its revival of the scientific spirit, a "unicorn horn"—actually a narwhal tusk marketed by canny Scandinavian seamen, could, according to one authority, "buy a city" for its ability to detect poison. As late as the seventeenth century the French imposed a duty of fifty sous per pound on unicorn horns brought into the country.

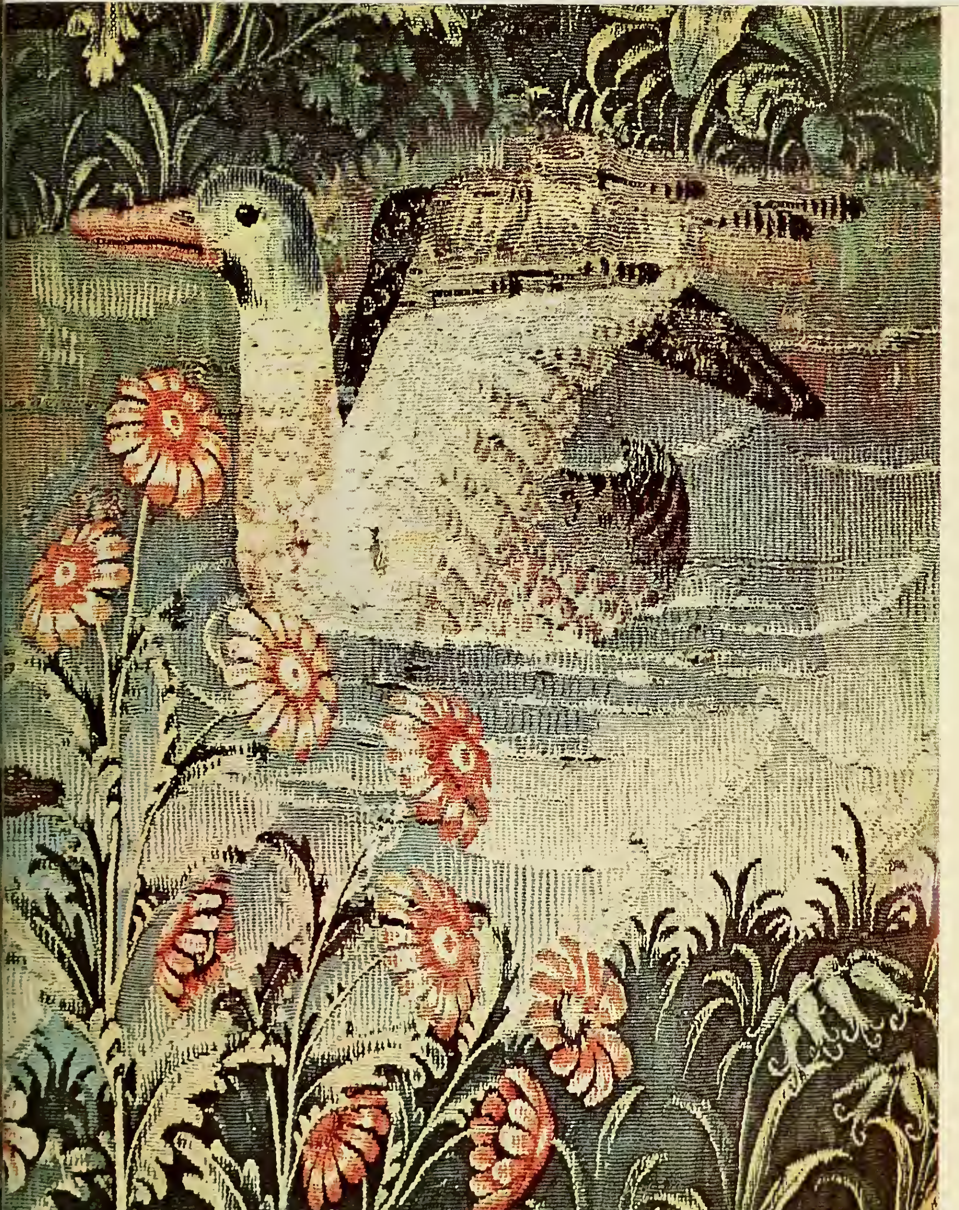
In the unicorn tapestries, myth and almost photographic realism are interwoven. Scholars have explored this realism, and have identified the royal figures, the hunting dogs, and even 85 per cent of the 101 different kinds of plants represented. Oddly, however, one facet of the tapestries



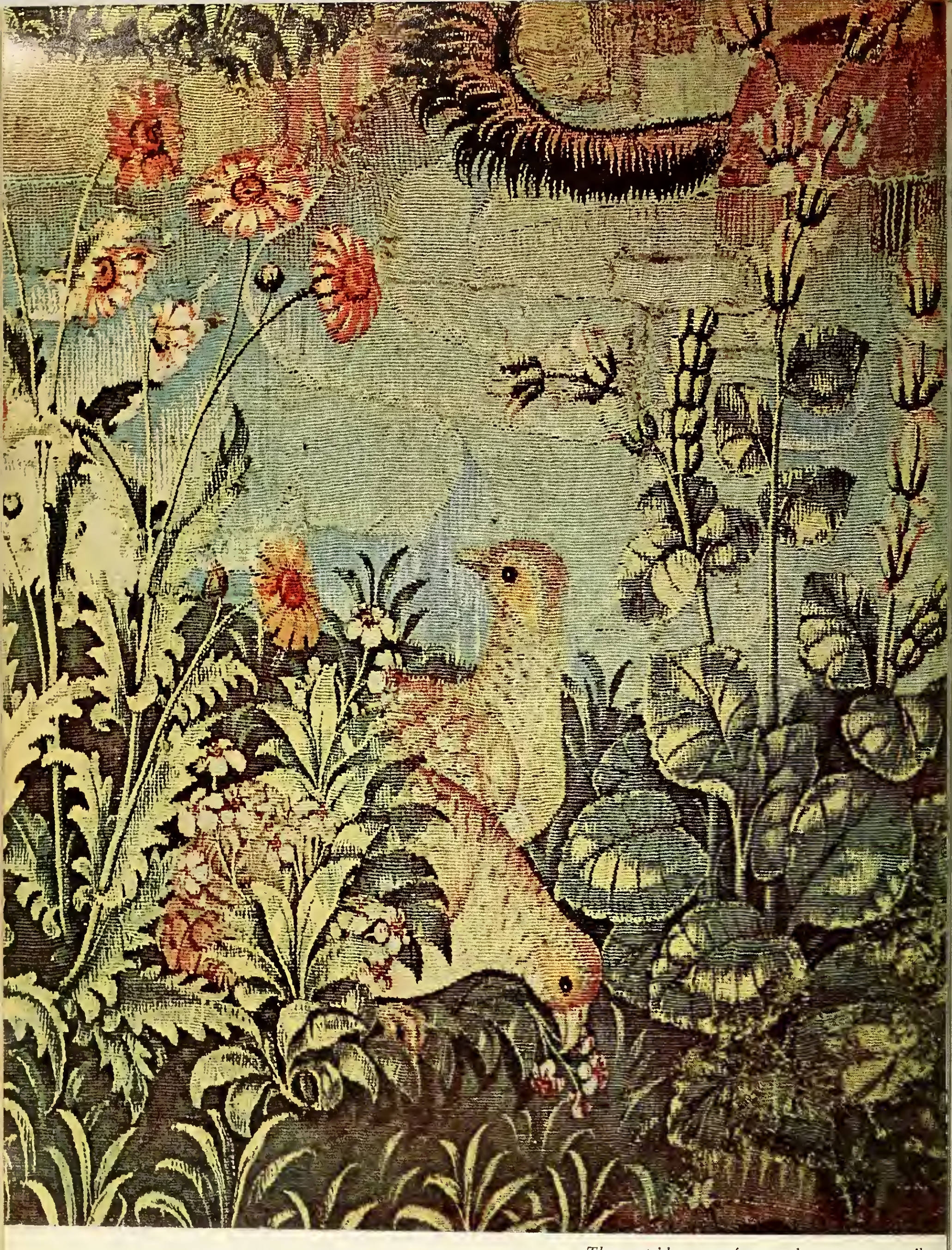
The sixth tapestry's vivid colors and three-dimensional treatment are particularly striking. Six tame doves are near cote and two swans adorn castle pond.



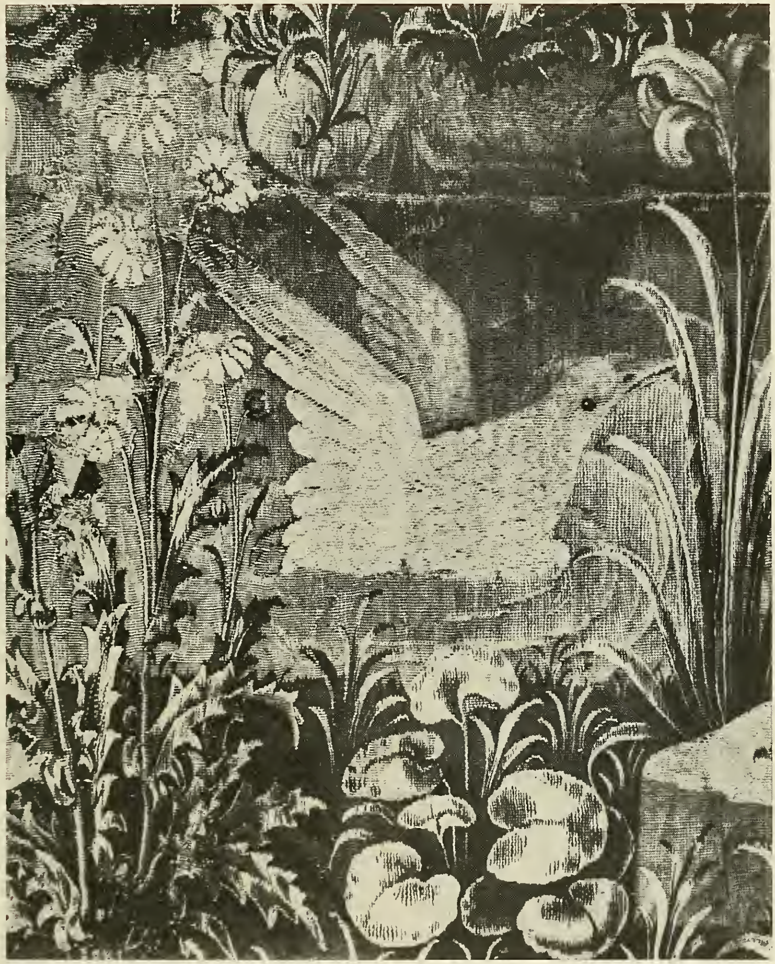
A woodcock and a mallard on stream in fourth tapestry are surrounded by broad-leaved pinks, at left, corn marigolds, center, and English bluebells, right.



Late Gothic tapestry techniques differed sharply from their predecessors in using shadings that gave life to even the most intricate and delicate of subjects.



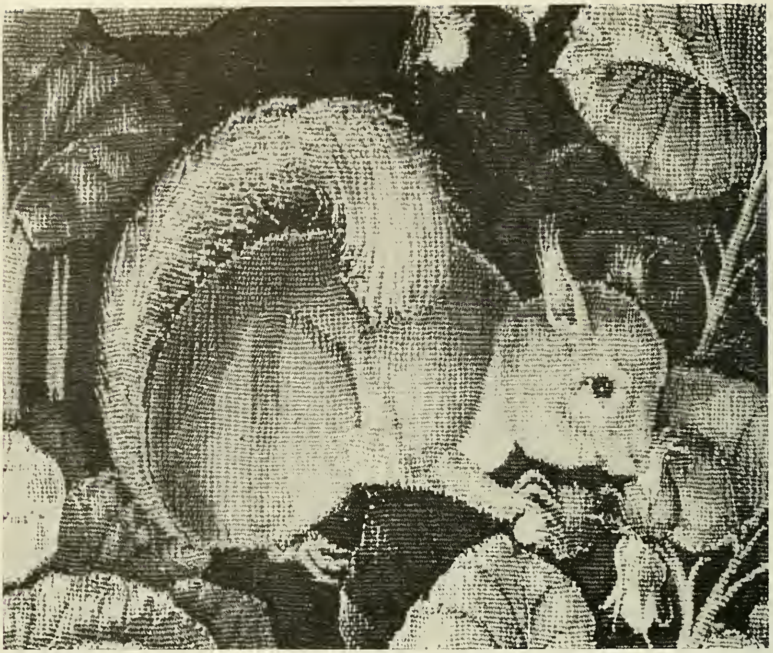
The partridge was often used to represent evil, so birds' appearance in this tapestry probably rested on their familiarity rather than on symbolism.



A domestic white duck, its wings outstretched to show that it has just settled on the water, swims near a shore on which are field daisies and a yellow flag.

has been largely overlooked. On leaves, in streams, in a pool, on treetops, and on a fountain edge are birds: all told, thirty birds (and two disembodied tails) of about thirteen different species. Most of them can be identified. But why were these particular birds chosen? The unicorn is symbolic. Do the birds have mystical significance, too? Perhaps this question can best be answered, at least speculatively, by considering the hangings and their contents one by one.

The first and last tapestries, entitled "The Start of the Hunt" and "The Unicorn in Captivity," are the two that may have been done about 1515 for Francis I. Neither of these includes birds in its highly stylized design. The five earlier tapestries are infinitely more realistic. Flowers of the marsh are shown in marshy places, perching birds are found in trees, and aquatic birds in the



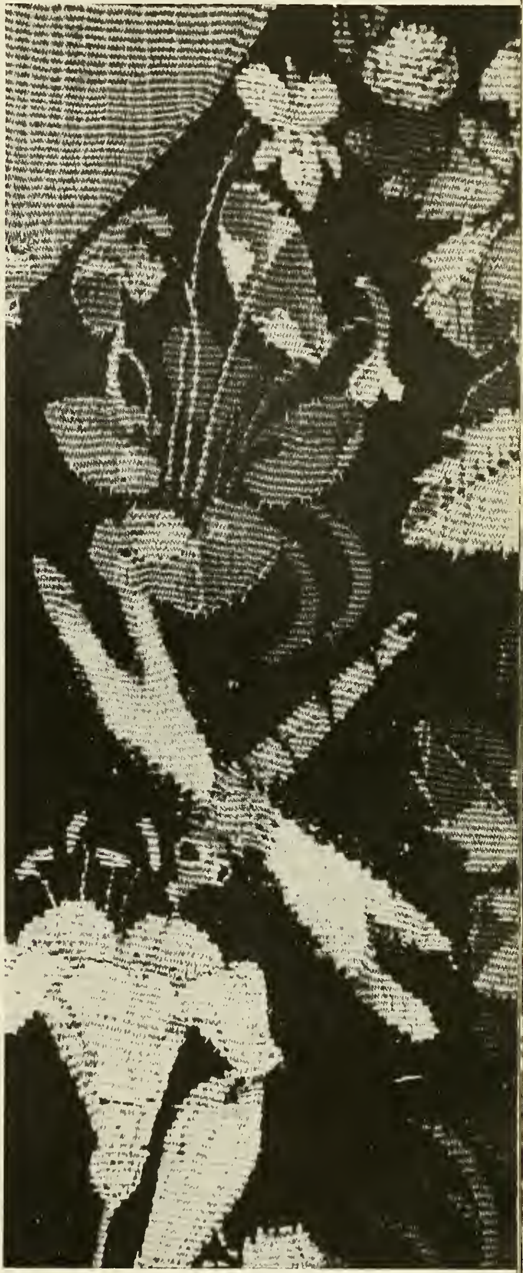
Some scholars believe that the squirrel had special significance for Anne of Brittany, as it also appeared with her in an earlier tapestry and a painting.

water. Of these five hangings, "The Unicorn at the Fountain"—the second in the series and the first made for Anne of Brittany's marriage—is perhaps the best known. In the center stands an elaborate fountain (pp. 40-41), below which, dipping its horn in stream water, in its classic duty of absorbing poison, kneels the unicorn. On the rim of the fountain are four birds. Two are pheasants, and opposite them are two European goldfinches, one a young bird whose black adult markings have not developed. In the foliage to the left of the fountain are another goldfinch and a bird that is either a willow warbler, a nightingale, or an imaginary cross between the two. This bird's yellowish breast suggests the warbler, but its rusty tail indicates that it is a nightingale. In the stream can be seen the tail of one duck disappearing into foliage, another duck (perhaps a cross between a mallard and a domestic breed), and a woodcock.

It is perfectly possible to lean on allegory to explain why most of these birds are in the tapestry. Birds have represented the souls of men and dozens of other religio-mythological aspects of man's beliefs from the times of Paleolithic scratchings on rock. Pheasants have been considered "thunderbirds." The goldfinch, which is fond of eating thistles and thorns, became an accepted Christian symbol of the Crucifixion because of the relation of all thorny plants to the Passion. The nightingale, believed propitious to weddings (and this tapestry was made for the union of Anne and Louis), also was a symbol of devotion, while ducks were augurs of the weather. The woodcock, alone, apparently has no symbolism attached to it in any culture. Thus it seems odd that, if allegory had been the avowed intention of the tapestry designers, this bird should have been included at all. The anti-allegory point of view can be made stronger by an inspection of the succeeding tapestry, "The Unicorn Tries to Escape." The first bird we notice is one flying from the very top of a tree at the hanging's upper left. The bird is probably another goldfinch, although repair in this area has been so extensive that it is hard to be certain. In the stream that runs along the bottom of the tapestry are several other birds. One of these in some ways defies identification (see page 31, *top*). It most closely resembles a little bittern, whose breast feathers are rusty colored in nesting season. In the center, a pair of partridges peer out between clumps of clary and field daisies (see page 36). Again, if symbolism were the artists' intent, the partridge would hardly have a place here. In legend, these birds are lascivious, cunning, depraved. It seems more logical to believe that the partridges were introduced because they were common game birds. Completing the stream-edge picture are a mallard and a domestic white duck, representations of fowl that certainly were very familiar to the Flemish artisans.

"THE Unicorn Defends Himself" is the fourth tapestry. Here another goldfinch flies from an upper tree limb, while two woodcocks and two mallards busy themselves in or near the stream. But in this striking work is another bird. In the lower right is an imposing figure—very similar to our great blue heron (see the cover). Now, if one is to seek symbolism, here it is. The purple heron is indigenous to Flanders, and it has been suggested that the legendary phoenix is really the purple heron (as *phoeniceus* means "purple"). Unfortunately for symbolists, the tapestry bird much more closely resembles the gray heron, a common frequenter of Flemish marshes and streams, than it does the purple heron.

The sixth tapestry (the fifth is only a fragment depicting a portion of the maiden, a hunter, and the unicorn) displays "The Unicorn Brought to the Castle." In this work, the royal couple in the center are probably Anne and Louis. Here, again, two goldfinches are to be found. Allegorically, the pair could represent the Resurrection,



Dragonfly, one of several in the tapestries, hovers over madonna lily. Above the insect is an easily recognizable violet plant.

The staff of NATURAL HISTORY wishes to thank MARGARET B. FREEMAN, Curator of The Cloisters, a branch of the Metropolitan Museum of Art, for her generous co-operation, which made this article possible. Photographs were taken by LEE BOLTIN.

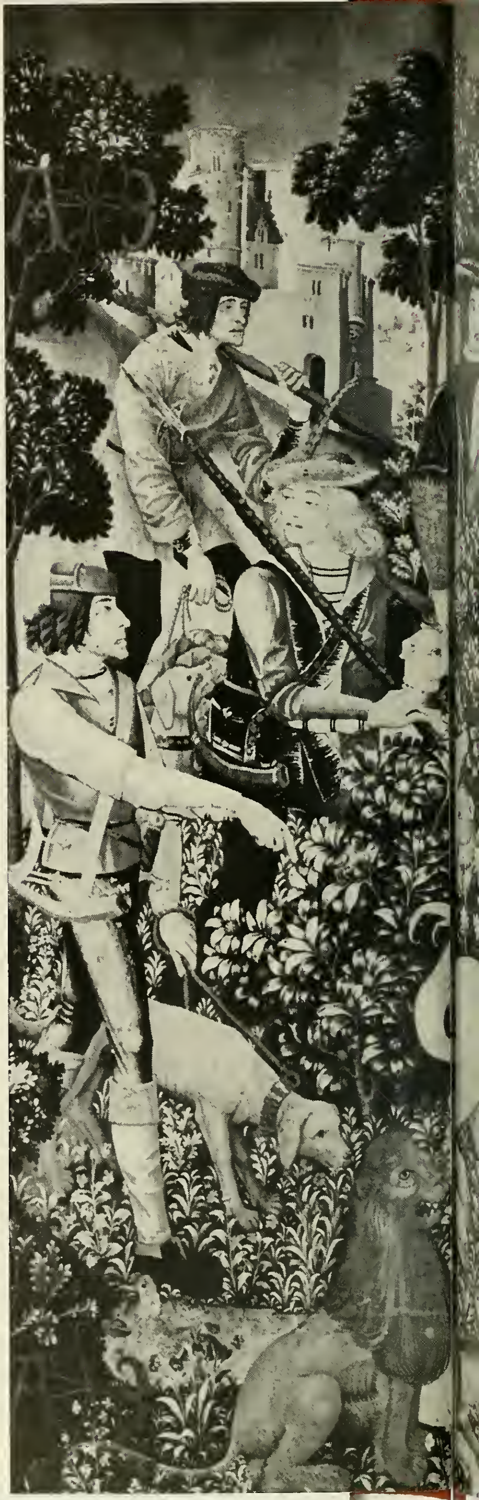
a theme in many contemporary works, or they could be augurs of disease. Historically, in contrast, these small birds were familiar to Flemish town and country dwellers alike, and were often kept as pets by children, who tethered them on strings.

In the center of this tapestry are two swans and a flock of doves (see page 33). Certainly swans meant good luck, while doves represented congregations doing good work. But, allegory aside, both birds were ordinary adjuncts to the aristocratic households of the late Gothic period.

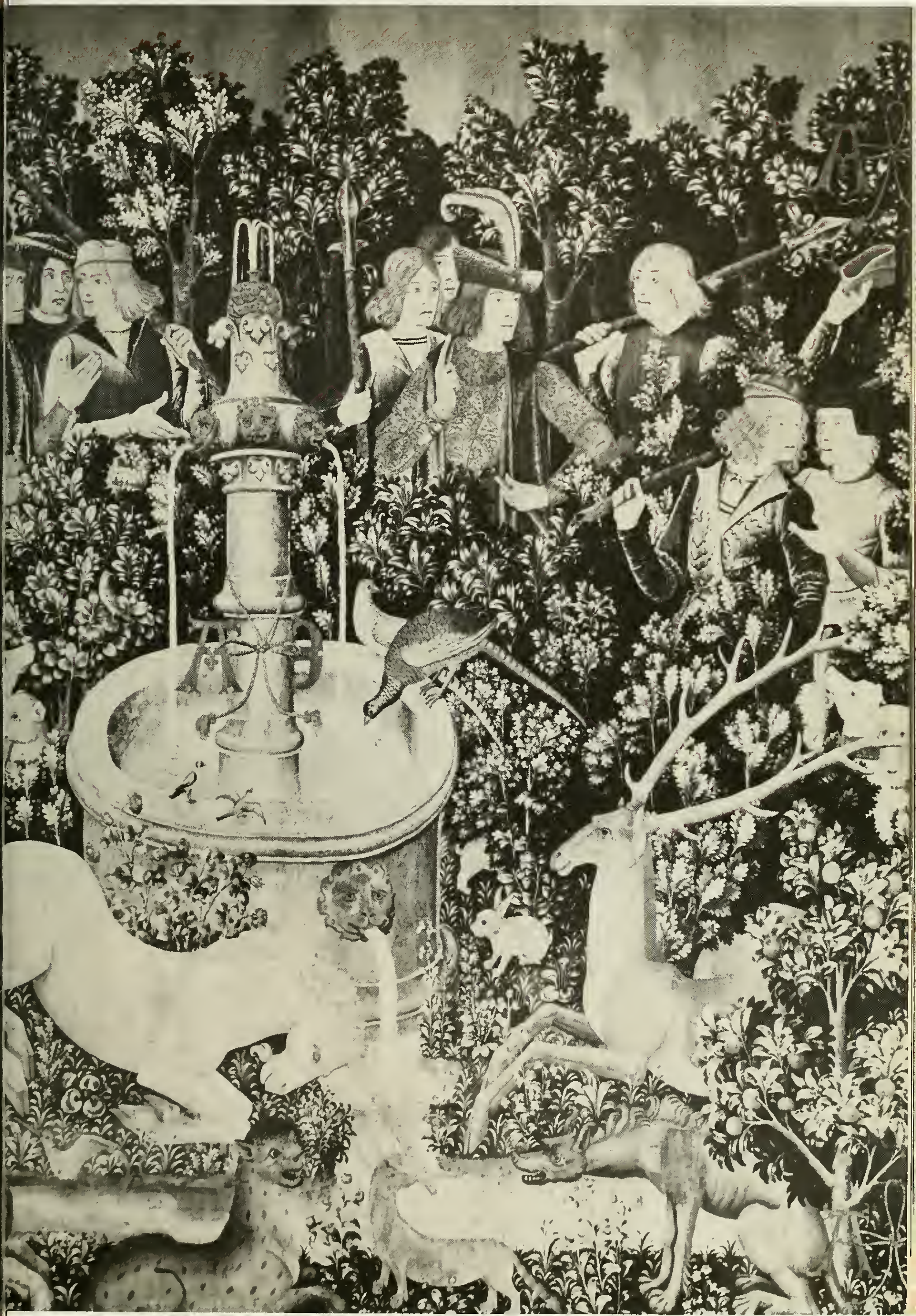
WE must conclude that while tapestry artists may have used symbolic material, they gathered it by observing the exciting natural world around them that revealed its realistic beauties.

Today, these seven tapestries march in an eye-filling procession round the gallery assigned to them at The Cloisters. In all but one of the great hangings, in the company of real royalty, realistic huntsmen, or identifiable birds, flowers, and dogs, strides or fights the genuine allegory—the great white animal whose horn is a sure cure for all passion, for epilepsy, worms, and plague.

From pre-Christian days to the twentieth century, the unicorn—an animal composed in equal parts of rhinoceros, antelope, goat, and faith—has been captured eternally. Immortalized in bronze, oils, ivory, and marble, the mystic beast is nowhere more magnificently enshrined than in the tapestries that bear its name, caught in the threads of its own mythos and serenely unaware that it is an anachronism in an intellectual climate in which truth, not legend, was considered to be the ultimate in beauty.



"The Unicorn at the Fountain" provides endless clues to the manner of life and thought in France of the late Gothic period.



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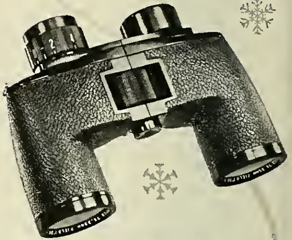

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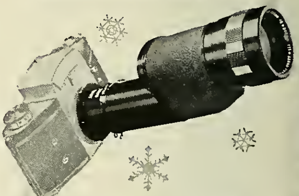

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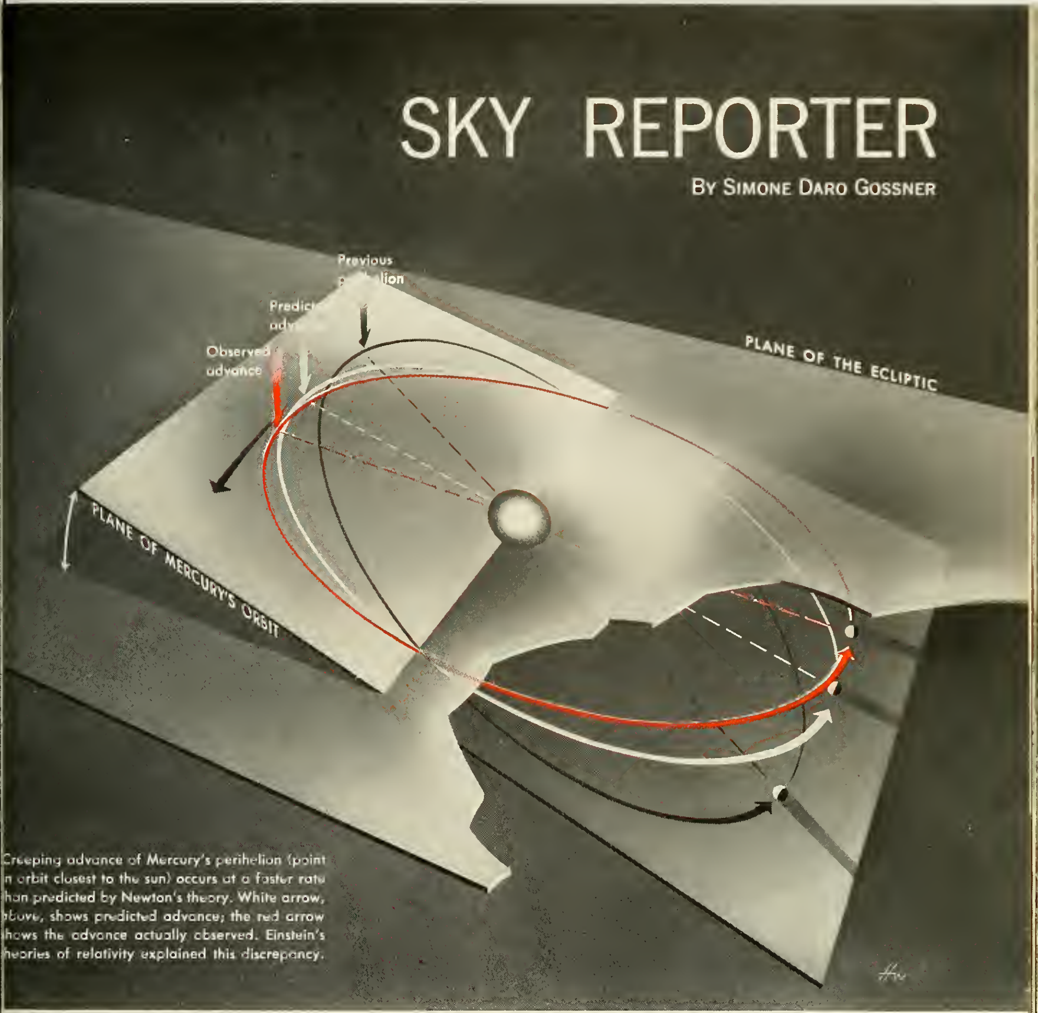
SKY REPORTER

By Simone Daro Gossner



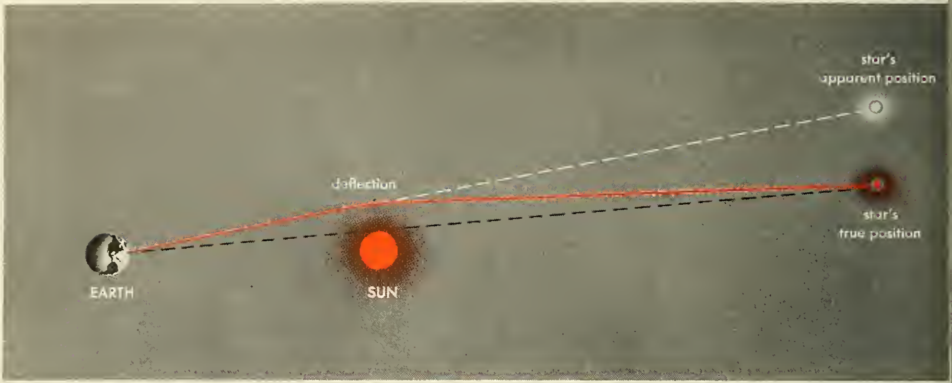
Creeping advance of Mercury's perihelion (point n orbit closest to the sun) occurs at a faster rate han predicted by Newton's theory. White arrow, bove, shows predicted advance; the red arrow hows the advance actually observed. Einstein's heories of relativity explained this discrepancy.

Modern astronomy and its proofs of the theory of relativity

As in all sciences based on the interpretation of observed data, a recurrent problem in astronomy is that increasingly precise observations eventually reveal minute phenomena, which can no longer be explained by existing theories. In some cases, it is sufficient to introduce slight modifications into current hypotheses; but at times an adequate explanation demands the adoption of an entirely new system of assumptions and physical concepts.

At the beginning of the twentieth century, it was a well-known fact in celestial mechanics that the motion of Mercury in its orbit could not be accounted for *exactly* by Newton's theory. Mercury's perihelion (the point in its orbit nearest the sun) is *expected* to creep gradually in the plane of the orbit under the combined attraction of the sun and planets. In other words, the entire orbit is slowly rotating in space (see diagram, *above*). But it is creeping *faster* than Newton's theory predicts. The additional displacement amounts only to about 43 seconds of arc, or less than 1/30,000 of a circumference, per century. Yet this small quantity is readily observed and was a cause of nagging concern to nineteenth-century astronomers. Several phenomena in the domain of physics, such as the behavior of light in certain experiments, were equally puzzling and at variance with current theories.

Radically new ideas concerning the velocity of light and the concept of time were propounded by Albert Einstein in 1905, in his *Special Theory of Relativity*. A few years later, in 1916, his *General Theory of Relativity* directed itself more specifically to a new interpretation of the motion of matter in the universe. The word "matter" is



Deflection of light by massive bodies, diagramed above in exaggerated fashion, was a further Einstein prediction.

Apparent position of a star (white), viewed close to the sun's edge, is compared here with its true position (red).

used here advisedly: not only did the new theory pertain to the motion of familiar celestial bodies, but it dealt also with the motion of light rays themselves, insofar as they behave like streams of material particles.

From the mathematical equations of Einstein's 1916 theory, it was possible to predict three astronomical phenomena capable of being verified by observation. All three have been found to exist. Although their effects are very small, and therefore difficult to measure accurately, the numerical results of the measurements are in good agreement with the predicted values of Einstein's theory.

One cannot, in these few pages, present the reasoning that led Einstein and his followers to their startling conclusions. The peculiar vocabulary of relativity does not lend itself to short definitions. Although the three predicted astronomical phenomena receive a rigorous formulation in Einstein's theory, the reader is cautioned to remember that they are described here in analogies of more elementary notions. The end result is the same, but the justification is necessarily approximate.

The first of these phenomena is the already familiar advance of the perihelion of Mercury. Its cause may be inferred from an analogy. We are taught that the shortest distance between two points is a straight line; yet if a ship sails from New York to Cherbourg, it is obvious that it cannot travel in a straight line because it must follow the earth's curvature. For the shortest trip, it must travel along a geodesic line (better known as a "great circle route"). Relativity assumes that the presence of a massive body, the sun in this case, creates what may be termed a curvature of the surrounding space. Admittedly, there is nothing tangible to this curvature, but it is used as a convenient mathematical representation. As with a ship sailing the ocean, a planet travels around the sun along a geodesic of the curved space. When the equations of such a motion are developed, it is found that the planet will return to perihelion after each revolution precisely in the manner revealed by observation. This excess motion of the perihelion decreases as the distance from the sun increases. Thus it is greatest for Mercury, but is still appreciable for Venus and the earth, and has been observed for all three.

The second phenomenon is usually called the *Einstein shift* or *gravitational red shift* (see diagram, *right*). The color of light and the pitch of sound, both of which travel in a wave pattern, are determined by the frequency of the wave (the number of wiggles per second, if you wish): high frequencies correspond to the blue end of the color spectrum (rainbow) and, in air waves, to high-pitched sounds, whereas low frequencies are characteristic of the red end of the spectrum (and of airborne, low-pitched sounds). If a sound emitter is approaching the observer, the wave pattern is compressed between the observer and emitter, the frequency is higher, and so is the pitch of the sound. Conversely, if the emitter is receding from the observer, the wave pattern is stretched out between the two, and the pitch is lower. A familiar example of this effect is the sudden drop in the pitch of a railroad train whistle as it passes your crossing. Similarly, if a light source is approaching the observer, its color will be bluer than if the source were at rest, and if it is receding, its color will be redder. This is the Doppler effect or (in the last case) the red shift. The Einstein shift, in turn, arises from different causes—there is no motion of source with respect to observer—but the net result is the same.

If a ray of light originates on the surface of a star, for example, Einstein's theory assumes that the star's massive body holds it back, so to speak, by its gravitational attraction. This is equivalent to the stretching of the sound waves mentioned above. When the wave length of that light ray is measured in a laboratory, it is compared with that of a terrestrial light source produced by the same substance. But because the earth is less massive, the wave length of the terrestrial source is stretched to a much lesser extent, and the stellar source appears redder by comparison. This, in essence, is the gravitational red shift. Such an effect is difficult to measure in the case of the sun (although this has been done) because it is inextricably mixed with true Doppler effects, caused by motion of gases in the solar atmosphere. It has been measured successfully for the small, but very massive, companion of Sirius. It should be readily understood that the effect is opposite, and thus becomes a blue shift, when the observer's laboratory is located in a site where gravitational attraction is greater than at the place of origin of the source being measured. For example, such a blue shift would be detected if we could measure with great accuracy the wave length of a light source generated in a small artificial satellite, in comparison with a terrestrial source.

The third astronomical phenomenon predicted by General Relativity is the deflection of light rays by the gravitational attraction of massive bodies. Einstein assumed that, in its travel through space, a ray of light behaves like a stream of material particles. When the light rays coming from a star pass in the immediate vicinity of the sun, the particles are subject to the space curvature caused by the sun's gravitational attraction and must therefore follow a geodesic. The net result is that the rays are slightly deflected (see diagram at left). To a terrestrial observer, the star appears slightly displaced from its true position. This effect is greatest (about 1.75 seconds of arc) for stars sighted near the edge of the sun, and falls off rapidly as the angular distance from the edge increases. For that reason, it can be observed only during total solar eclipses, when stars are visible in the immediate vicinity of the sun. The star field surrounding the sun is photographed while the eclipse is in progress, and again several months later when the sun has moved to another part of the sky: the gravitational displacement of the star images is determined by comparing the two photographs. Theoretically, stars other than the sun would cause similar deflections of light rays, but there is no convenient way of observing this. The existence of the Einstein deflection was confirmed for the first time from observations of the solar eclipse of May 29, 1919, a scant three years after publication of his *General Theory of Relativity.*

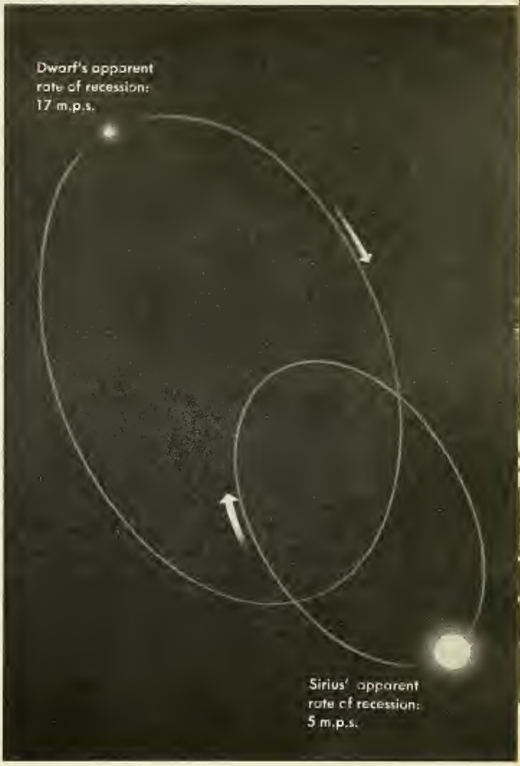
The theories of Einstein have been used extensively by modern cosmologists to construct—figuratively speaking—mathematical models of the universe. Although the existence of "island-universes" had been a matter of philosophical speculation for at least two centuries, it was only in 1925 that Edwin Hubble, astronomer at the Mount Wilson Observatory, obtained indisputable proof that the nebulae (now called galaxies) are vast stellar systems outside our own Milky Way. In 1929, by applying the principle of the Doppler red shift, he discovered that galaxies are receding from the Milky Way with speeds roughly proportional to their distances. This does not imply that the Milky Way Galaxy is at the center of the universe, but merely that the entire universe is in a state of expansion comparable to that of an immense balloon being inflated. Because all dimensions of the "balloon" are increasing simultaneously, any two points chosen at random inside it will appear to drift away from each other.

THE Belgian G. Lemaitre had demonstrated in 1927 that one of the models of the universe that may be constructed on the principles of relativity happens to be an expanding one. It should be pointed out, however, that Hubble's discovery of the red shift of galaxies does not necessarily prove the validity of Lemaitre's model to the exclusion of all others. The only established fact in this respect is that, from observational data, one may be reasonably sure that the universe is currently in a state of expansion, and that relativistic theories are among those that are capable of accounting for this fact.

Models derived from the principles of General Relativity may be divided into two broad categories: the "big bang" models and the pulsating ones. The first category, which includes Lemaitre's, assumes that the age of the universe is finite (in the order of 10 billion years) and that the expansion started explosively from a highly concentrated state, or "primeval atom." The others, on the contrary, consider that the age of the universe is infinite and that it undergoes successive periods of expansion and contraction, each one lasting many billions of years.

DURING the past decade, a number of models have been proposed, which, are no longer based on the principles of relativity. The most famous of these is the "steady state" theory, which assumes that matter is continuously created in the universe, probably in the form of hydrogen atoms in the vast spaces between galaxies. These atoms are presumed to condense eventually into new galaxies.

Unfortunately, it is impossible to decide between these conflicting models because they postulate events—the birth of hydrogen atoms in intergalactic space, an explosion that happened aeons ago—which cannot be verified by observation. In a few hundred years, they may well seem as quaint as the stars on the goddess Nut of ancient Egypt.


Dwarf's apparent rate of recession: 17 m.p.s.
Sirius' apparent rate of recession: 5 m.p.s.

RED LIGHT of Sirius' dense, dwarf companion, *right,* gives another proof of relativity theory. Dwarf star appears to be receding at net speed of some twelve miles per second.

THE SKY IN DECEMBER

From the Almanac:

New Moon	December 7, 6:52 P.M., EST
First Quarter	December 14, 3:06 P.M., EST
Full Moon	December 21, 7:42 P.M., EST
Last Quarter	December 29, 10:57 P.M., EST

The sun will be at the winter solstice on December 21 at 9:20 P.M.. Eastern Standard Time; winter will begin on that date in the Northern Hemisphere.

For the visual observer:

Mercury, in the morning sky for the first half of December, will be in superior conjunction on December 16 and will enter the evening sky on that date. As a result, it will be too close to the sun for observation.

Venus (–3.4 magnitude) will rise one hour before the sun on December 1. and 45 minutes before the sun on December 15. The planet may be observed as a morning star in the early part of the month, but its angular distance from the sun will diminish gradually. By the end of the year, Venus, like Mercury, will be lost in the sun's glare.

Mars (+1.5 magnitude) will be in conjunction with the sun on December 14 and will enter the morning sky on that date. Mars, too, is unfavorably located for observation in December because of its proximity to the sun.

Jupiter, in Capricornus (–1.6 magnitude), will set in the southwest at 8:45 P.M.. local time, on December 1, at 8:00 P.M. December 15, and at 7:15 P.M. December 31.

Saturn, in Sagittarius (+0.8 magnitude), will be approximately 7° west of Jupiter during the entire month and will set about 45 minutes before that planet.

During the evening of December 10/11, the moon will pass about 2° north of Jupiter and Saturn. The lunar crescent will be only three days old at that time, and the two planets should be seen clearly in its vicinity.

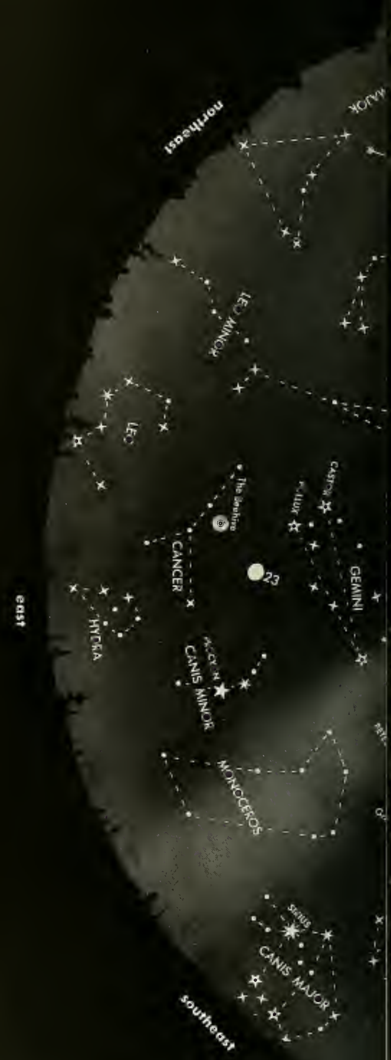
The Geminid meteor shower will reach its peak on December 13. Its maximum rate is estimated at 50 meteors per hour (for a single observer). As its name indicates, the meteors belonging to this shower will appear to radiate from a point in the constellation Gemini.

New Year's Day:

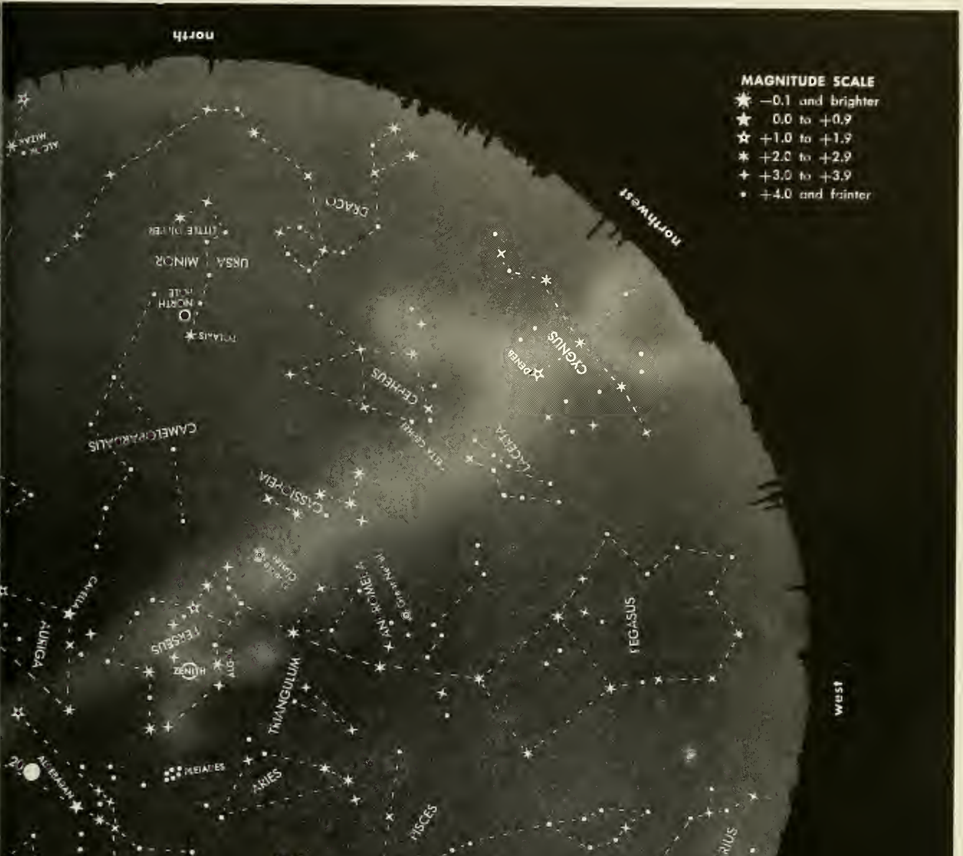
Contrary to what might be surmised, there is no astronomical phenomenon corresponding to the beginning of the calendar year. As a matter of fact, January 1, itself, has not always heralded a new year in the Christian world. Until two centuries ago. March 25 played that role in England and its territories, including the American colonies. When England switched from the Julian to the Gregorian calendar (in 1752), it concurrently adopted the western European practice of beginning the year on January 1. For a time after the change was made, and in order to avoid confusion, dates within the overlapping period were written in both styles, thus: January 18, 1754/5.

It should be noted that the term "style" refers specifically to the date on which the year begins (Annunciation style for March 25, Circumcision style for January 1). In the English-speaking countries of the world, however, the expressions "old style" and "new style" are frequently applied to the Julian and Gregorian calendars, respectively.

On the preceding pages. MRS. GOSSNER offers the last in her 1961 series on the growth of cosmological concepts.



To use this map outdoors, hold it in such a way that the direction you wish to face is printed at the bottom. The constellations depicted below the point marked "zenith" are visible in that part of the sky at the time indicated.


north
northwest
west
southwest
south
MIZAR
ALCOR
DRACO
LITTLE DIPPER
URSA MINOR
NORTH POLE
POLARIS
CEPHEUS
DELTA CEPHEI
CYGNUS
DENEB
LACERTA
CAMELOPARDALIS
CASSIOPEIA
Double Cluster
ANDROMEDA
Great Nebula
CAPELLA
AURIGA
PERSEUS
ALGOL
ZENITH
GEMINI
TRIANGULUM
PEGASUS
20
ALDEBARAN
PLEIADES
ARIES
PISCES
TAURUS
17
14
AQUARIUS
CETUS
ERIDANUS
FORNAX

MAGNITUDE SCALE

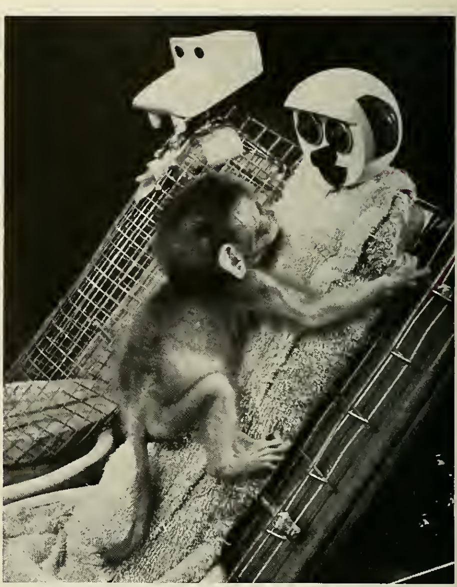
✶	−0.1 and brighter
★	0.0 to +0.9
☆	+1.0 to +1.9
✳	+2.0 to +2.9
✦	+3.0 to +3.9
•	+4.0 and fainter

TIMETABLE

December 1	11:00 P.M.
December 15	10:00 P.M.
December 31	9:00 P.M.

(Local Standard Time)

Normal mothering, with infant monkey clinging to the parent for comfort of contact, typifies first ninety days of life.



Terry cloth "mother" gave substitute contact comfort to one group of infants, which matured in good physical health.

A Study of Animal Affection

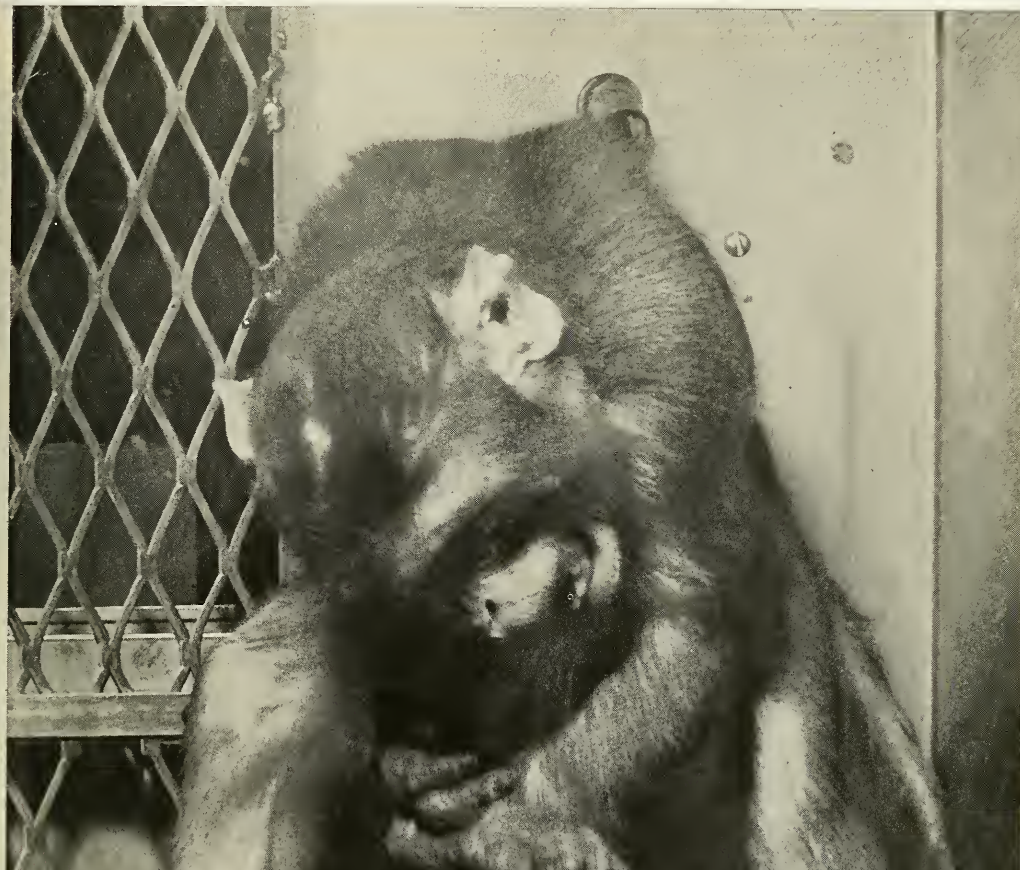
Deprived of mothering and play, monkeys remain infantile

By Harry F. Harlow and Margaret K. Harlow

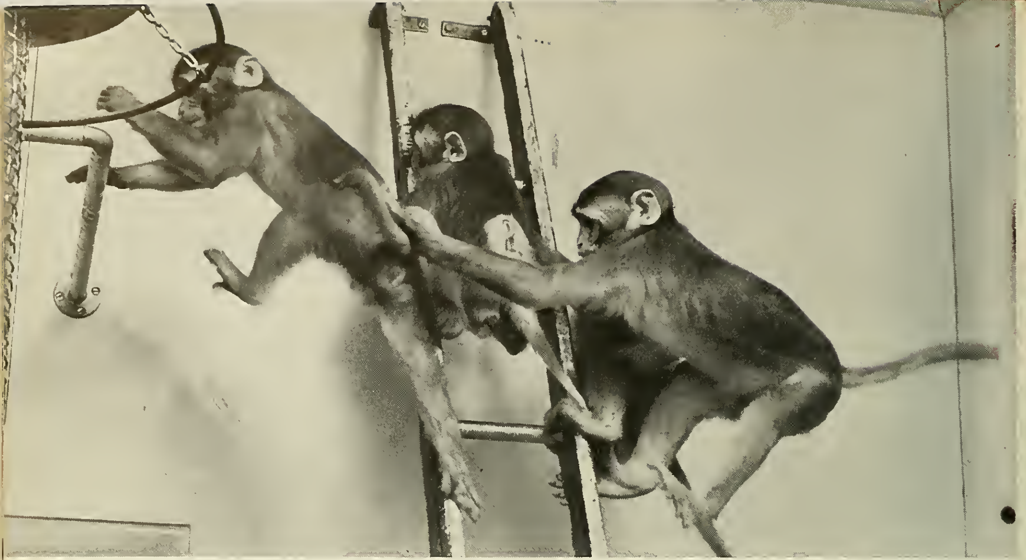
Eight years ago we established a rhesus breeding colony at the University of Wisconsin's Primate Laboratory to provide a steady supply of healthy, newborn monkeys for intensive study of learning and intellectual development from the day of birth until attainment of full capacities. Only by controlling the environment from birth is it possible to trace development under constant conditions. We controlled the monkeys' environment — and, consequently, their life experiences—by removing each baby from its mother within 6 to 12 hours of birth and placing it in a wire cage in a nursery where it could see, hear, and communicate with other babies but not make bodily contact.

During the early months, the babies were treated much like human babies, with bottle feedings, supplements, and gradual transition to solid foods. The babies thrived. Mortality was much lower than for babies raised by their own mothers, and illnesses were few. They were a strong, healthy group of monkeys, and 55 of them underwent regular daily testing on a variety of learning and perceptual tasks. At a year of age, the rhesus young were promoted from the nursery to larger, individual cages in another room, where they continued as subjects in the developmental project. It was planned that, after they finished their jobs in this long-term project, they would be consigned to the breeding colony to provide a steady supply of healthy babies for other research, including the tracing of affectional development from birth onward.

We had not expected to use these particular animals in the analysis of affection. However, they have accidentally proved to be very helpful as subjects. At the same time, they have proved to be almost worthless as



IMMATURE MALE RHESUS shows stereotyped behavior of the emotionally disturbed (handclasping, *above*). This monkey, now over three years old, grew up with a manikin "mother." Often withdrawn and passive, these animals cannot be bred.



Manikin-mothered infants, in groups of four, were allowed to play together, daily, for eighteen months in a special cage, *above*. Although lacking real parent-child experience, they developed playmate relations, as did normal young.

breeding stock: these healthy, educated, laboratory-reared monkeys simply have not been productive as parents.

But before we go into the group's unanticipated procreative problems, we need to introduce the reader to our researches on love and affection—studies still in progress although initiated over five years ago.

Our first experiments on love and affection were designed to discover the variables that tie infants to their mothers: that is, the infant-mother affectional system, the first to appear in the development of the individual—monkey, human, or subprimate. For this research, a second group of newborn monkeys was isolated. Because monkey mothers, like human mothers, vary greatly in behavior toward their infants—ranging from highly devoted and protective to neglectful and even abusive—we controlled this "mother variable" by fabricating substitute mothers whose frames were made of wire, sheet metal, and wood. All the "dummy mothers" gave physical support. Some provided nourishment by means of formula fed through a nipple protruding from the chest; some provided the comfort of a soft, textured skin—a terry cloth body covering. Later experiments introduced mother models with new attributes, all studied under carefully controlled conditions: some of these "mothers" had rocking motion, some provided body warmth, and some varied the angle of incline.

A few of these early studies have already been described (Natural History, May, 1960). In summary, our data led to the inescapable conclusion that contact comfort, through softness and warmth, was the crucial factor in the development of the infant's love for its mother. When the animal is still very immature, it prefers a mother that also provides nursing, rocking motion, and a less steep incline than our standard models. Later, when the baby moves about with ease, these added provisions are of no importance at all: the baby divides its time equally between cloth mothers with and without an additional feature other than warmth, even though it has been reared from birth with access to both models.

In all, about 90 infants reared on such artificial mothers—one mother or two mothers each—have reached maturity. Like their cage-raised, motherless relatives, they are healthy, strong animals and have been consigned to the breeding colony. But these animals, too, are producing few babies, in spite of intensive efforts to rescue them from their celibacy.

Even before we discovered that we had raised large numbers of abnormal animals, we had already undertaken studies of three other affectional systems of monkeys: infant-infant (or peer) affection—the attachment of young monkeys to others of their age group; heterosexual affection—which appears in complete and full form in adolescent and adult animals; and the maternal affectional system, or mother-infant affection. Large bodies of data are already available delineating the development of the infant-infant system, and there are sufficient results on the next two systems to enable us to draw some firm conclusions about them and about the affectional deficiencies in both cage-raised and manikin-reared babies.

The infant-infant affectional system is the second to appear in the individual's life span, and we have studied it in several experimental situations. Our initial infant-infant study introduced groups of four babies each, one group at a time, into a playroom. Inside were a platform, a ladder, a rotating wheel, and flying rings, which enabled the animals to move about and exercise in a three-dimensional world. There were also many toys and puzzle devices. The groups were together daily for 20 minutes in the playroom but lived in individual cages with cloth mothers the rest of the time. During the course of more than 18 months, we found a series of stages in the infants' play and interrelationships.

The first stage was presocial, during which the babies explored and manipulated all the objects in the room, including other monkeys, but did not engage in any play with each other. It is highly similar to the first play stage of human infants and young children. The next stage was rough-and-tumble play, during which the babies romped, wrestled, rolled, and tussled in furious encounters (although no animal was ever hurt in this play). The third stage, approach-withdrawal play, was characterized by pairs of monkeys chasing each other back and forth without necessarily engaging in any physical contact. The fourth stage has been described as integrated play: it involved both rough-and-tumble and approach-withdrawal and frequently gave rise to brief play patterns of "frantic frenzy." incorporating any and all of the objects in the room (photo, *left*).

The fifth stage, aggressive play, began to appear near the end of the first year. It was characterized by biting and pulling but involved little or no bodily hurt. Gradually, this changed to a stage of true aggression, in which the animals established their dominance positions in the group. But no serious injury occurred, probably because the monkeys had gained skills of evasion as well as attack during the more relaxed and carefree stages of infant-infant affection. Characteristically, one monkey grabbed another's fur, or ear, or leg with hand or mouth, pulled, twisted, and tore, and sometimes even drew blood. Such behavior gradually reduced; subsequently social play ceased. Thus social order and status were established, as in a neighborhood play group, and at the same time, firm affectional bonds, formed earlier, remained.

The third affectional system, chronologically, is the heterosexual system, and it develops from early infancy through maturity. Like the other affectional systems, it goes through a series of stages, and at least three can be clearly identified: an infantile stage; a stage of sex play; and a stage of mature sexuality. In the infantile stage, overt sex behavior is relatively limited and the patterns of sex behavior are typically fragmentary and incomplete. However, from the first month of life onward, little males and little females could be identified in terms of the frequency of certain selected patterns of behavior. Females show increasing frequency of passive behavior while males show an increasing frequency of aggressive behavior, as indicated by patterns of facial and bodily threat. Even though sex behavior is fragmentary and incomplete, there is a progressive tendency for the male animal to show patterns of attempted mounting and thrust and for the female to show the patterns of crouching and presenting. From six months onward, there is very little overlap between the sexes in these specific patterns.

Among the wild-raised and mother-raised rhesus monkeys at the laboratory, full-blown, normal sex patterns are relatively frequent during the second year of life, before either sex is mature. There is no evidence for any biological latency period. With mature partners, the basic patterns are performed in sequence (and with completion when the females reach maturity in the third year of life and the males in the fourth year).

The fourth affectional system that we studied is that of maternal affection. Primarily we observed this system in our playpen situation, which consists of four large, wire-mesh living cages, one for each mother-infant

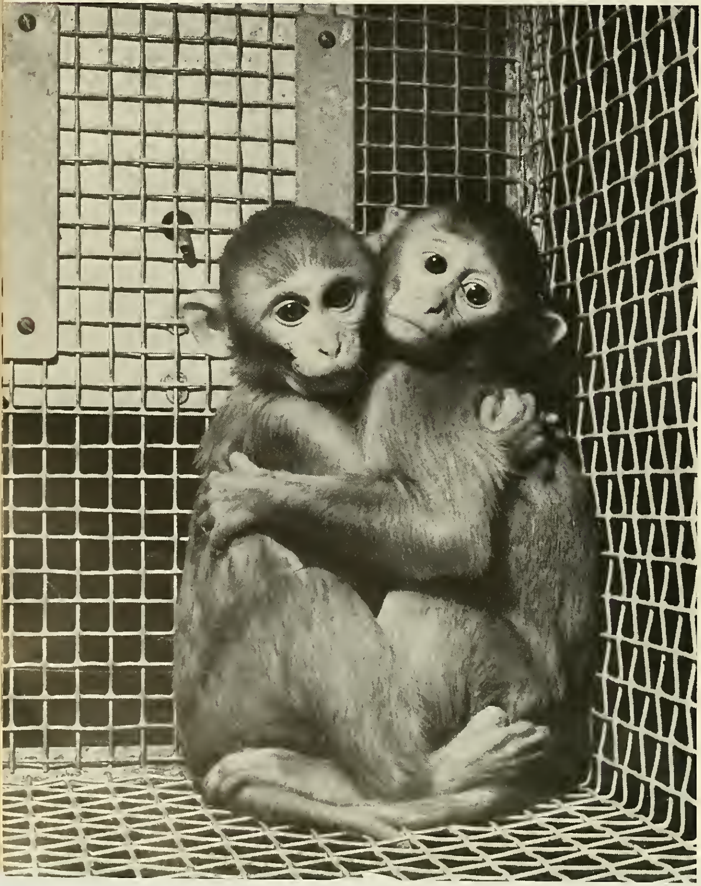
Cage-raised female, deprived of both real parent and manikin, is example of severe neurotic disturbance. Only one such cage-raised female has conceived.

pair, and four playpens. Each cage-playpen unit has an opening large enough to permit free passage of young monkeys but too small for the mother. The panels between adjoining playpens are raised one hour a day, permitting pairs of babies and, subsequently, all four infants to interact.

THE maternal affectional system can be traced through three stages: a stage of attachment, a stage of ambivalence, and a stage of separation. The attachment stage begins at delivery, or shortly after, and continues for about 90 days. (Typical maternal behavior in this period is shown in the photograph on p. 48, *left*.) During the first several days after delivery, many (and probably most) mothers show attachment and affection toward all baby monkeys and will adopt or even steal other babies if given the chance. Subsequently, most mothers show strong attachment and protective responses only to their own (or previously adopted) babies. Although one of our mothers has been kind and acceptant of all babies throughout the first year in our playpen situation, she appears to be exceptional. The other mothers have all become aggressive toward other infants, and this aggression has been noted to coincide with the time the babies start engaging in rough-and-tumble play. While the babies are actually wrestling, the mothers watch closely and suffer, as indicated by growling, snarling, and shaking the cages, and should a retreating baby come into the wrong mother's cage, it is apt to be forcefully ejected. The mother of the ejected baby then shows disapproval of the other mother by still fiercer growls and cage-shaking.

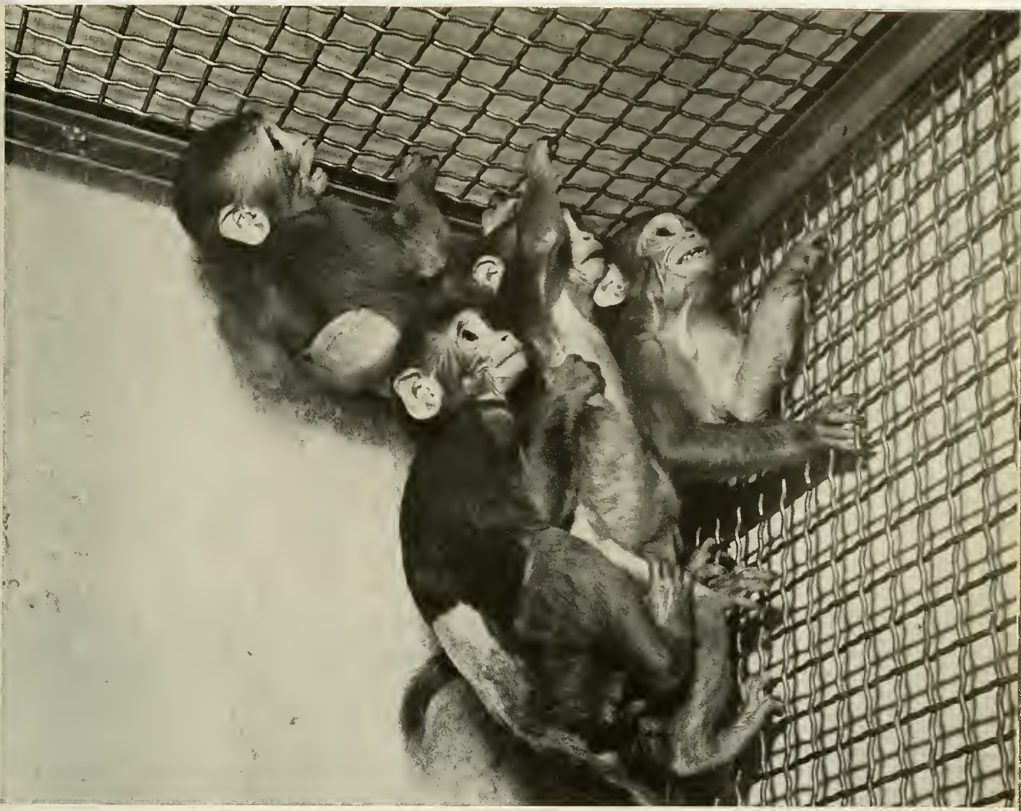
The DRS. HARLOW are a husband-wife team of psychologists whose current project is described here. They are at the Primate Laboratory of the University of Wisconsin, where he is also Professor of Psychology.

PAIR OF INFANTS, taken from parents in "self-mothering" experiment, learned to embrace tightly, *below*, so that each had the comfort of mother-like contact.



From 90 days on, the protective and comforting responses of the mother to her own infant decrease and the punishing responses increase: this behavior characterizes the stage of ambivalence. The mother does not really abuse her baby, but from time to time she resists its approaches and its demands upon her time and person in a decisive and vigorous manner. Throughout this period, the baby continues to use the mother as a source of security, and at night mother and baby are in close physical contact.

It is at this point in our studies of the affectional systems of the monkeys that we may relate our findings to human behavior. It has become apparent through the years that basic to the problems of many neurotic and psychotic humans are abnormalities in affectional relationships originating early in life. Case histories suggest that the infant's failure to form satisfactory affectional relationships—particularly with the mother and often with the father—can lead to subsequent failure to find satisfactory relationships with parent substitutes and with peers first, with mates later, and with offspring still later. Fortunately, not all emotionally deprived infants and children show this sequence of problems, but so many of the mentally ill do that it is of interest to attack the problem experimentally. One cannot, of course, use human subjects, but it is especially fitting to use monkeys, for these animals closely resemble man. The goal is first to demonstrate that normal, healthy babies, born to behaviorally normal monkey parents, can be rendered neurotic or psychotic by controlling their early emotional and social experiences. This could help to establish indirectly that mental illness is not necessarily determined by constitutional abnormalities or inherited weaknesses, as some still believe. Beyond this, through success in producing disturbed animals, we can trace effects on subsequent generations of animals raised by the disturbed animals. The over-all goal is to provide data that might enable us



SELF-MOTHERING QUARTET, in parallel experiment, showed a different pattern of behavior. They did not form pairs to embrace in ventral contact-clinging but, instead, lined up in what experimenters called a "choo-choo train" pattern.

to prevent needless psychological crippling at the level of human beings.

The first and plain fact is that, without intent, our efforts to control the environment had already produced two large groups of abnormal monkeys. Our 55 cage-raised animals — the "motherless" group — were deprived of both mothering and monkey companionship in the first three years of life. Our 90 manikin-reared animals had special kinds of mothering —inadequate though they were—and they also went without monkey companionship in their first years of life.

DAILY observation for as long as six or seven years has revealed various behavioral aberrations in the motherless group, behavior not commonly noted in monkeys captured in the wild or those raised in group-living situations. Many of these "deprived" monkeys, especially the older ones, sit passively in their cages and stare vacantly into space, paying little attention to the monkeys in neighboring cages or to the activities of workers in the room. Some show peculiar stereotyped behavior such as clasping their head or body in their arms and rocking back and forth for long periods of time. Others show patterns of self-punishment, such as seizing an arm with the mouth and tearing at the flesh until blood flows. This is all behavior that one can observe repeatedly in severely withdrawn patients in mental institutions.

Exposed, in test situations, to each other and to monkeys of their own age captured in the wild, these motherless animals have been consistently less responsive to other monkeys except for fighting, in which they engage freely. Unlike normal animals, they avoid opportunities for social contacts such as are customary among peers.

In breeding attempts, the motherless females have been paired with patient males from the breeding colony, and the motherless males have been paired with experienced females. In several years of repeated trials, no motherless male has ever achieved intromission, although these animals have shown sexual excitement. Often they have engaged in violent assault against the female, forcing us to remove the male. After years of testing, *one* motherless female has to date been impregnated (more a triumph of the male than the female). Generally these females have avoided the males or assaulted them, showing only fragments of the normal sex patterns.

The dummy-mothered monkeys have been somewhat less disturbed, as one would predict on the basis of degree of deprivation and age, but their behavior nonetheless has been distinctly abnormal. They tend, like the motherless monkeys, to sit passively in their cages, staring vacantly and paying little or no attention to other monkeys or to people. They rock, suck their body parts, and ex-

AUTHOR holds a nine-month-old rhesus from the Wisconsin University colony.

hibit both stereotyped patterns and self-aggression, but in general they do so in lesser degree and less frequently than do the motherless monkeys. They are a younger group, however, and may show more severe aberrations as they grow older.

The majority of the cloth-mothered animals are sexually mature. Yet none of the males has achieved any semblance of normal sex behavior, even though they show sexual excitement during mating opportunities. The females have been slightly more responsive, no doubt because their role is relatively passive compared with the male's, although success has been achieved only with three and only after numerous exposures to selected breeding males.

RECENTLY we have produced bizarre behavior in eight monkeys in situations we call "self-mothering." Four infant monkeys were placed as pairs in standard living cages, and four other infant monkeys were placed as a group in a considerably larger cage. The monkeys living as pairs have shown a progressive tendency to maintain a tight ventral clasp similar to the contact clinging of baby monkeys to real or cloth mothers (photo, p. 52). We call this "together-together" behavior. These two together-together pairs have been tested in the playroom, from birth onward, for more than a year and have shown almost no play. When they were approaching their first birthday, they were re-paired, kept in their cages for three weeks, and then reintroduced to the playroom. They showed no sign of affection for their original partners and made no effort to contact them. Instead, they maintained their tight clasp with their current partners.

Returned to their original partners for three weeks and then retested, they rapidly sought out and clung to these original partners, their then-current living companions. These animals appear to be arrested in their affectional development at the early attachment stage seen in our infant-mother studies. It seems likely that contact clinging, established between newborn monkeys, destroys infant-infant—and probably all subsequent—affectional development.

The behavior of the group of four self-mothered animals differed somewhat from that of the two pairs. Instead of going into patterns of tight ventral contact clinging they tended to line up in a row with one monkey in the lead, the second clutching the leader's back, the third clutching the second's back, and the fourth hanging on or close to the third, "choo-choo train" pattern (photo, p. 53). From time to time, one or more of them would break away and roam about the enclosure, but soon it would be shackled by the others and find itself dragging two or three cagemates. Tested in the playroom, they showed practically no indication of any play behavior. Their affectional and social behavior seems, like that of the self-mothered pairs, to be arrested at the early infantile attachment stage.

No member of the together-together pairs and none of the "choo-choo" foursome has shown any sign of the development of heterosexual behavior. We are almost certain that, when they attain puberty and adulthood, they will be as sexually handicapped as the monkeys previously described.

At the present time, we have very limited data on the effect of early mothering experience on the child's maternal affectional pattern, but we have discovered enough to present some fairly suggestive findings. As already stated, through the use o patient measures, one cage-raised an three cloth-mothered females wer successfully bred. All are now raisin their babies in a playpen situation.

The first mother paid no attentio whatsoever to her baby after it wa born but, instead, would sit in he cage staring vacantly into space. Sh gave no evidence of protective maternal responses either when her infar was threatened or when the experimenter took the baby away severa times a day for artificial feeding As soon as the baby could locomote it struggled desperately to establish normal contactual relationship wit its mother. It would climb on it mother's back only to be brushe away by the mother as if she wer brushing off flies. When the bab persisted, the mother would crush th baby's face or body down on the floo

NEUROTIC MONKEYS, *right*, are mature male (foreground) and female, both of them cage-raised from birth. Deprived of normal upbringing, they only brood.

of the cage with her hand or foot while either looking at the infant or staring blankly into open space. The behavior of the second mother was similar: she ignored her baby after birth and often struck or bit it until the infant screamed in pain.

The third mother initially ignored her baby or indulged in abuse: indeed, she was the most brutal of the three. However, this baby, through persistence, was able to establish a nursing relationship with the mother from time to time. After the first few days, we were not forced to feed it.

This in no way means that the mother was normal, since the baby succeeded in making contact with her only a fraction of the times it tried. Even when it succeeded, the mother treated it in a passively acceptant manner and showed only very mild defensive reactions when the baby was threatened. Normal mothers clasp their babies tightly and show violent threat behavior when an outsider comes near their cage. Any belief that maternal affectional patterns were really formed by this third mother was dispelled during most observational periods. Very frequently the mother would either sit on the cage floor or hang by her feet from the ceiling and strike the baby repeatedly with her open hand without provocation of any kind.

The fourth mother is somewhat more passive than the others. Although she has abused her baby, she is less violent and nurses her baby.

DATA derived from these atypical mothers are most compelling. We cannot be sure, of course, whether their failure to show normal maternal behavior stems from their motherless (or inadequately mothered) infancy, from their lack of association during the first years of life with other infants and young monkeys, or from both factors. We only know that these monkeys without normal mothering and without peer affectional relationships have behaved toward their infants in a manner completely outside the range of even the least adequate of normal mothers. They constitute our most dramatic discovery to date in the production of abnormal affectional behavior, and we wait with eagerness to trace their subsequent personality development and the personality development of their unlucky babies as they grow, mature, and, in the case of the females, become mothers themselves. We have failed in some efforts to make mechanical rejecting "mothers," but we have triumphed without intent in flesh-and-blood ones.

Endangered Relic Trees

The West's rare trees are becoming rarer

By Paul D. Kilburn

It is scarcely surprising that California, the state with the greatest ecological variation in the United States—where habitats stretch from below sea level to over 14,000 feet, and climates vary from desert heat to alpine cold—should possess a world-famous aggregation of tree species. Many of these trees are confined within the state's boundaries and, in fact, more than 1,400 of the total vascular plant flora (some 4,000 species) are restricted to the state. Others spill over, but only slightly, into the geographically similar parts of neighboring states and Mexico.

Many of these endemic plants are extremely rare, found only on a particular island, desert, or mountain. For years, some desert annuals exist only as viable seeds, awaiting sufficient moisture to break their dormancy and enable them to grow and blossom. But better known than these annuals are several tree species that cling to life precariously in small areas. These relics, remnants of the former widespread forests, emphasize that extinction is always a possibility and that a slight change in the environment could easily eliminate them. Such has often been the case in the past, for extinction has been a corollary to evolution. While the number of plant species is enormous (upwards of half a million), many more than this number became extinct as natural selection weeded out those species that could not adapt to a changing environment. But such extinctions took place slowly; organisms had but to adapt gradually to a changing environment in order to remain alive.

Today a new environmental force, acting with extreme rapidity, faces all biota—namely, man and his actions. This force has the ability both to eliminate and to propagate. With wisdom and foresight, man can be the means of insuring survival of the isolated stands of trees discussed in this article; with carelessness, as has been the case all too often in the past, he can be the means of their total and irreparable destruction.

The list of rare California trees is too long for this article—many of the rarer ones, such as gowen cypress and oracle oak (a hybrid that is also found in Oregon) are not included. Those that are discussed are the more famous, and often possess features of particular interest in addition to rarity. Not all are botanically rare in the sense that they stand on the verge of extinction, but all those discussed are relics with narrow ecological distribution patterns. It is not absolute extinction they face, for individuals grown from seed adorn parks or streets throughout the world, but rather extinction in their native habitat. There they are truly relics.

The star of California's relic trees is that twisted coastline rarity, the Monterey cypress *(Cupressus macrocarpa)*. Fame has come to this species for its location on the seacoast of the Monterey Peninsula, about 100 miles south of San Francisco. The number of wild individuals of this tree is in the thousands, all growing within a few miles of each other on the rocky southern coast of the peninsula and Point Lobos, a few miles to the south. Here, they present a fitting adaptation to the strong, constant sea wind, molding themselves to the rugged rocks. This cypress is a short tree; the tallest is sixty feet, and its wide-spreading shape is much more typical of an oak than it is of a conifer. Dense foliage is produced by a thick growth of branches extending to the ground, where the trunk may be three feet thick. Although a poor timber tree, it makes an ideal windbreak near the ocean. Unfortunately, it apparently requires the sea fog to flourish, and its distribution is limited.

The cypress genus possesses severa species nearly as rare as this tree. Ir fact, few other genera of plants ar so uniformly restricted. None com bines the picturesque habitat, uniqu

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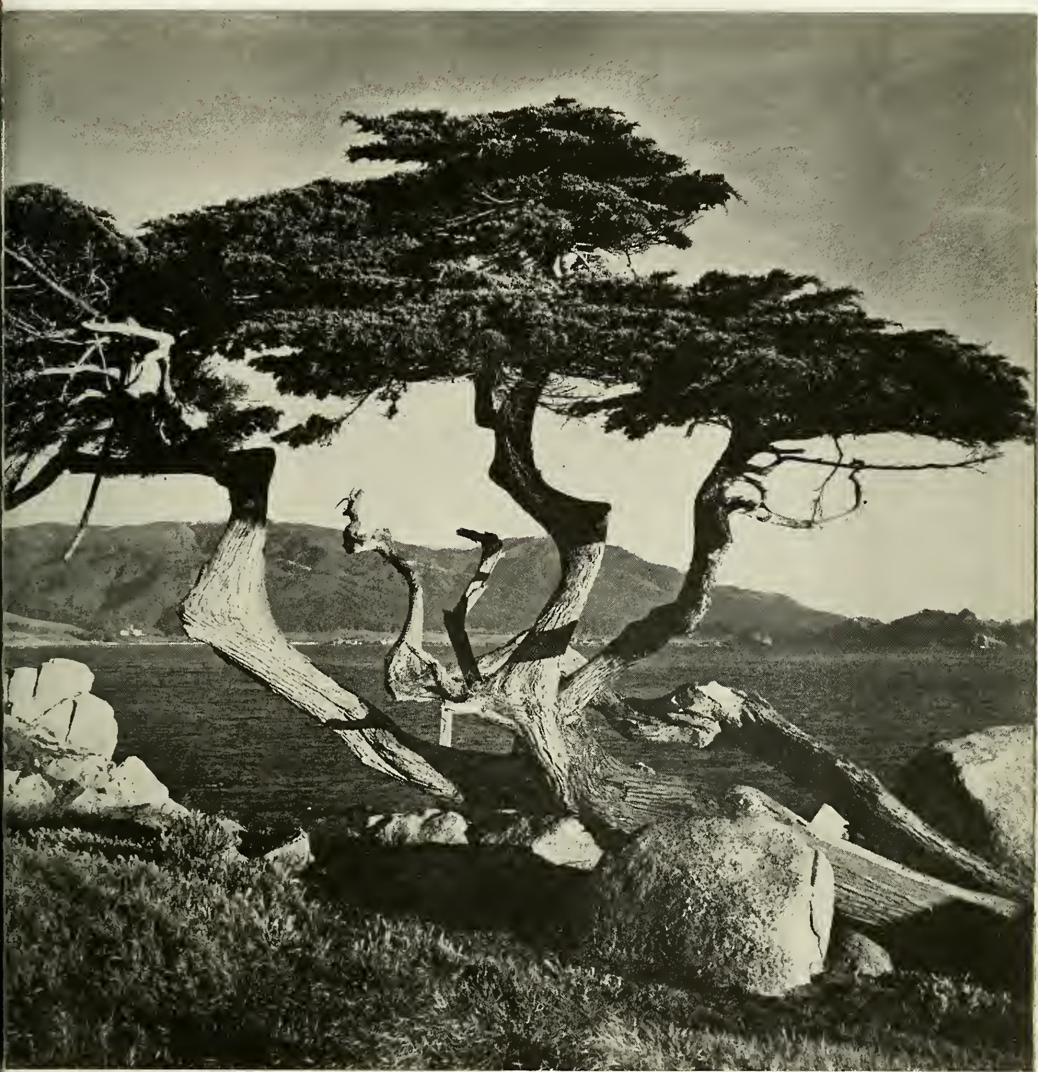


Monterey cypress, bent to grotesque, streamlined form by the constant gales from the sea, forms windbreaks along California shore, but declines inland.

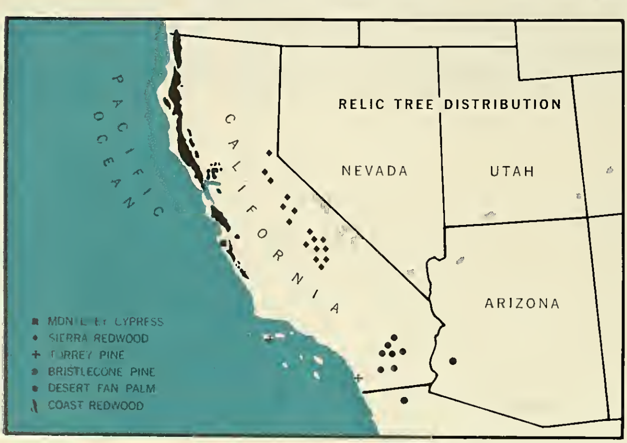
growth form, and accessibility of the Monterey cypress, and hence they remain unknown to the layman.

Two species of the formerly widespread genus *Sequoia* survive today in California. The coast redwood *(S. sempervirens)*, the world's tallest tree, occurs beyond California for some eight miles into southern Oregon, and is not technically confined to the state. This species, an abundant tree along California's northern coast, is still logged commercially. Valuable and enormous, it is a relic of the former widespread sequoia forest that once grew as far away as Greenland and Alaska in past geologic times.

Many redwoods tower 300 feet or more, but the tallest of this race of giants is found in the heart of the redwood belt, far north of San Francisco, at Dyerville Flat. Here the Founders Tree towers 364 feet above the ground, yet so tall are its neighbors and so accustomed to loftiness is the visitor, that this unbelievable height does not seem extraordinary from below. The diameter of the largest trees often exceeds 10 feet. Sometimes they attain 15 feet and, rarely, 20 feet, with a maximum of 22.5 feet; yet these girths rank well below those of the Sierra big trees.

Ecologically, the redwoods are confined to areas that receive the summer fog belts that roll in from the Pacific early in the afternoon, shrouding the tall giants in a cool, moist blanket until the late morning sun burns the cover away. Because of this dependency on ocean fog, the tree is never found more than 40 miles from the

Coast redwood, abundant on northern shores of California, is also found in Oregon and lumbered commercially. Those above grow along the Eel River.


RELIC TREE DISTRIBUTION
PACIFIC OCEAN
CALIFORNIA
NEVADA
UTAH
ARIZONA
■ MONTEREY CYPRESS
• SIERRA REDWOOD
+ TORREY PINE
● BRISTLECONE PINE
● DESERT FAN PALM
COAST REDWOOD

Pacific, and usually it is much closer. Thus, a narrow belt of redwoods extends from the Oregon border for some 450 miles down the northern coast of California, breaking down into scattered and separated ravine-bottom groves south of Big Sur, near the extreme southern range.

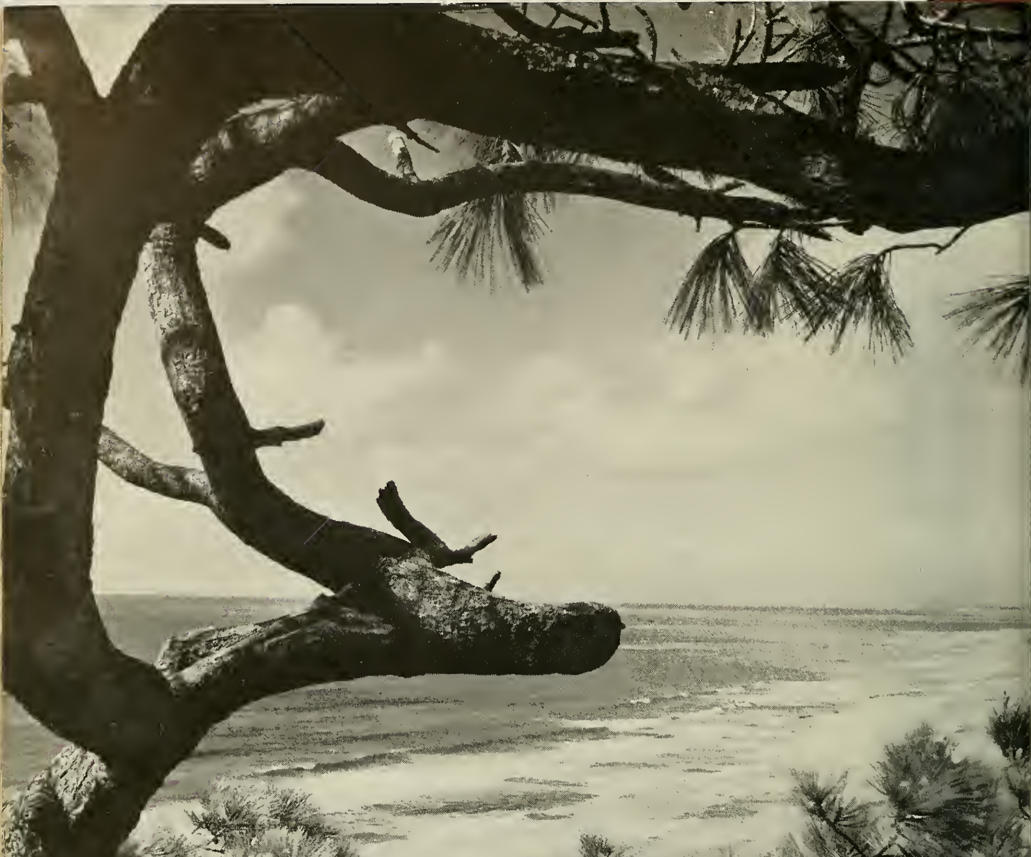
The work of preserving virgin stands of redwoods from logging for all time was undertaken jointly by the Save-the-Redwoods League and the state of California. As the result of this unified, co-operative venture, 65,000 acres of redwood land have been preserved. Much of this land is in small groves and parks near major highways, available for the enjoyment of travelers for many years to come. While logging the remainder of the stands goes on at a rapid pace by a highly organized industry, man can relax in the knowledge that his children will have many stands in which to wander, and that redwoods will provide multiple use—lumber, recreation, and solitude—for years to come.

A close relative, the Sierra redwood *(S. gigantea)* or big tree, the largest living thing, is a true relic of the western slope of the Sierra Nevada mountain range at elevations from 4,000 to 8,000 feet. The tree occurs in scattered groves over a north-south span of 250 miles. While not facing immediate extinction, it is a relic of wider distribution in the past. The big tree is probably the world's most impressive and famous tree. Although not one of the tallest trees, its unbelievable girth makes the observer's first impression one of disbelief. The tree dominates a forest in which wildlife abounds. It is an ideal spot for hiking and for photography, as the widely spaced trees and sparse undergrowth leave abundant light for pictures. Young sequoias are common here, for the tree reproduces well on exposed mineral soil, such as paths and road cuts, and the groves promise refreshment to visitors for many years to come.

SINCE the discovery of these groves in 1852, man has had a decided effect on the future of the trees. Of prime importance was placement of most of the groves in public ownership, where they can be protected and easily visited by everyone. This ownership pattern ended destructive logging on public land, an activity that aroused public opinion. Unfortunately, logging still persists on private lands.

We do not know the effect of the virtual elimination of fires—which have always been part of the natural environment of these trees—on their future. Nearly all the larger trees attest to former fires with charred bark and deep scars. Cessation of these fires has allowed a dense forest of white firs to spring up in many places, preventing young Sierra redwoods from becoming established. More research on the effect of purposely set, light fires to encourage sequoia reproduction is needed. Finally, man's trampling of the soil around famous trees and in the better-known groves may adversely effect the health of these giants. The Park Service, taking cognizance of the problem, has enclosed the most popu-

SIERRA REDWOODS are the largest of all living things. This is the General Grant Tree, 271 feet tall and over 20 feet in diameter for its first 100 feet.



Torrey pine may be the world's rarest tree. It grows wild north of San Diego and on Santa Rosa Island. Today, only 3,000 individuals are known to exist.

lar trees with fencing. This protection is needed for many others, however, as trampling has compacted the soil a foot or more around some trees. In the future, healthy stands will require close and intelligent management.

Several unusual pines, conifers of the genus *Pinus*, occur among those growing wild in California. Ranging in size from the short, squatty pinyon pine of the desert border to the tall, majestic sugar pines of the Sierra Nevada, this group is perhaps the most conspicuous of California's tree cover. Like conifers throughout the Northern Hemisphere, the pines grow in nature's ecological slums. Sturdy and abundant, they are found at desert fringes, on bare rocks, and at the highest timber lines.

Two of these pines evoke unusual interest—one bordering the Pacific shores, the other growing at high timber line. It is the former, a tree clinging to the bluffs of the Pacific at Del Mar, just north of San Diego (it grows wild in only one other place—Santa Rosa Island, just off Santa Barbara) that lays claim to the title of the world's rarest tree. Here the Torrey pine *(Pinus torreyana)*, represented by only about 3,000 small, twisted individuals, faces the steady and forceful sea breeze from the Pacific. This number appears large in comparison with figures on certain rare animals, yet in fact it is extremely small when the future of the species is at stake. A plant has no means of moving out of the way of fire or severe storms that could eliminate its wild populations. This tree is certainly on the verge of extinction.

Many of the pines near Del Mar are protected within Torrey Pines State Park and what a wild, magnificent collection of beach and coastal bluff flora is found there! The pines persist in gullies and ravines leading oceanward and dominate the vegetation, although few exceed 30 feet in height. Surprisingly, when planted in protected places the Torrey pine is majestic, straight, and fast growing. Thus we see that the growth form of this pine is obviously influenced directly by the environment.

But it is a relatively abundant pine, one found in several western states, that in California reaches its greatest age and becomes the "oldest living thing" in the world—the bristlecone pine *(Pinus aristata)* growing at timber line in the White Mountains near the Nevada border. Here, in the rain shadow of the Sierra Nevada, at 9,000 to 11,000 feet, occurs one of the strangest forests in the world. Its age and appearance makes discussion of the pine appropriate, even though it is not rare. The eerie woodland it dominates consists of very open stands of the massive, short tree atop the dry, rounded mountaintops. The needles of the bristlecone, although in clusters of five, are a mere one or two inches long, and are indicative of a long-continued adaptation to its high, dry habitat. The cones bristle, as the name suggests, and cluster easily within reach on all but the largest trees. Tree size is deceptive here, for the growing season is short and a tree ten feet tall may be seventy-five years old. The oldest veterans may be but thirty feet tall, with diameters two feet at breast height.

Bristlecone pine is the world's oldest living thing. Although small—some of most venerable are less than 30 feet high—trees may live over 4,000 years.

Age is evident in every branch of these trees; looking at them, one can almost feel the brunt of the severe winter storms the bigger trees have withstood. Many are dead except for a narrow strip of bark and living tissue leading from the roots to one remaining branch. The most impressive sight in the entire area is the aptly named Methuselah Lane, a steep slope on which many of the trees are more than 4,000 years old, and where the oldest one yet sampled, more than 4,600 years of age, still grows. Trees on this slope are often more dead than alive, yet stand silent guard over many fallen but undecayed individuals. Such falls represent centuries of accumulation, for decay proceeds very slowly on the rocky surface.

Youth is common in many of these forests, and young seedlings, two or three feet tall, are scattered about frequently. It is evident that although some mountainsides consist entirely of dying monarchs, most areas possess enough young trees to maintain the forests for a long time.

A perplexing feature in the forests is the presence of charcoal and fire scars on most of the old tree trunks. The open character of the trees and sparseness of the undergrowth make one wonder how such fires could spread, and what possible influence this has had on the distribution of the forests. Do the scars mean simply that the undergrowth was once shrubby, but has been killed by repeated burnings until only tiny annuals and rosette plants now exist? Does it mean that the absence of seedlings in some areas is the result of repeated fires? Answers to these questions must await more precise studies, including those at the Laboratory of Tree-Ring Research of the University of Arizona.

THE area including most of the California populations of bristlecones lies within the Inyo National Forest and is, of course, protected by the federal government. Already, improvements in the roads and campsites are under way and the area will certainly be visited much more frequently in the future. And visited it should be, for the view from these mountains across the Owens Valley to the rugged Sierra Nevada must rank as an outstanding scene in a state possessing many breath-taking views. One may absorb many lessons here in the solitude of what seems to be the top of the world. Particularly forceful is the wonder one feels in seeing such weird forest beauty in this harsh habitat. For the wind is strong and continuous, an unrelenting factor eliminating all but the best-adapted plants.

One more tree remains to be discussed—the picturesque desert fan palm *(Washingtonia filifera)*. This, California's only native palm, is not confined to the state, for a few are found in western Arizona and several in Baja California, but its unusual appearance and habitat, and its scattered distribution deserve mention. This—incidentally, the only palm native to the western United States—occurs in Southern California on the fringes of the low, hot Colorado Desert, which surrounds the Salton Sea. Here, usually in canyons and along streams issuing from the mountain ranges, the palm appears to be making its last stand against an increasingly hostile climate. In California, these tall, stately trees normally wear a thatched skirt of dead leaves that reaches nearly to the ground, and groves of these palms present a memorable sight. Groves vary in size from a few to many individuals depending on the number and size of mountainside streams or springs.

DR. KILBURN, a botanist with the Department of Biology at Principia College in Elsah, Illinois, is now working under a resident grant from the National Science Foundation. He is especially interested in applied, historical, and quantitative ecology.

One of the most extensive views of these trees and their habitat can be seen by looking east from the Palm-to-Pines highway, State Highway 74, some 3,000 feet up in the San Jacinto Mountains, overlooking the Coachella Valley. Far off in the distance rise the Little San Bernardino Mountains and below them are the Indio Hills. The palms appear as widely separated patches of green, dotting the base of these hills for miles. Closer approach reveals that they occur along the notorious San Andreas fault in places where streams and gullies dissect the hills. Here, exposed to the full blast of the desert sun on the south-facing slope, the palms grow in one of the world's most rigorous climates.

One can approach many of the groves readily, but the close-up view is often disappointing, for most of the trees have had their thatch burned off by man-made fires, and only charred trunks can be seen. Fire is a major enemy, since the thatch is highly flammable and burns with such heat that the terminal, leaf-producing area is often killed and the tree dies. Those that survive remind one of shorn sheep, differing from those animals in that they never regain their cover.

MOST of the trees are unprotected on private lands, although the largest grove in Palm Canyon, just south of Palm Springs, is owned and managed by the Santa Inez Indians. A few small groves are under National Park Service jurisdiction in the Joshua Tree National Monument. The trees do reproduce, however, and the occurrence of some seedling palms will insure the species' continuance for some time under natural conditions.

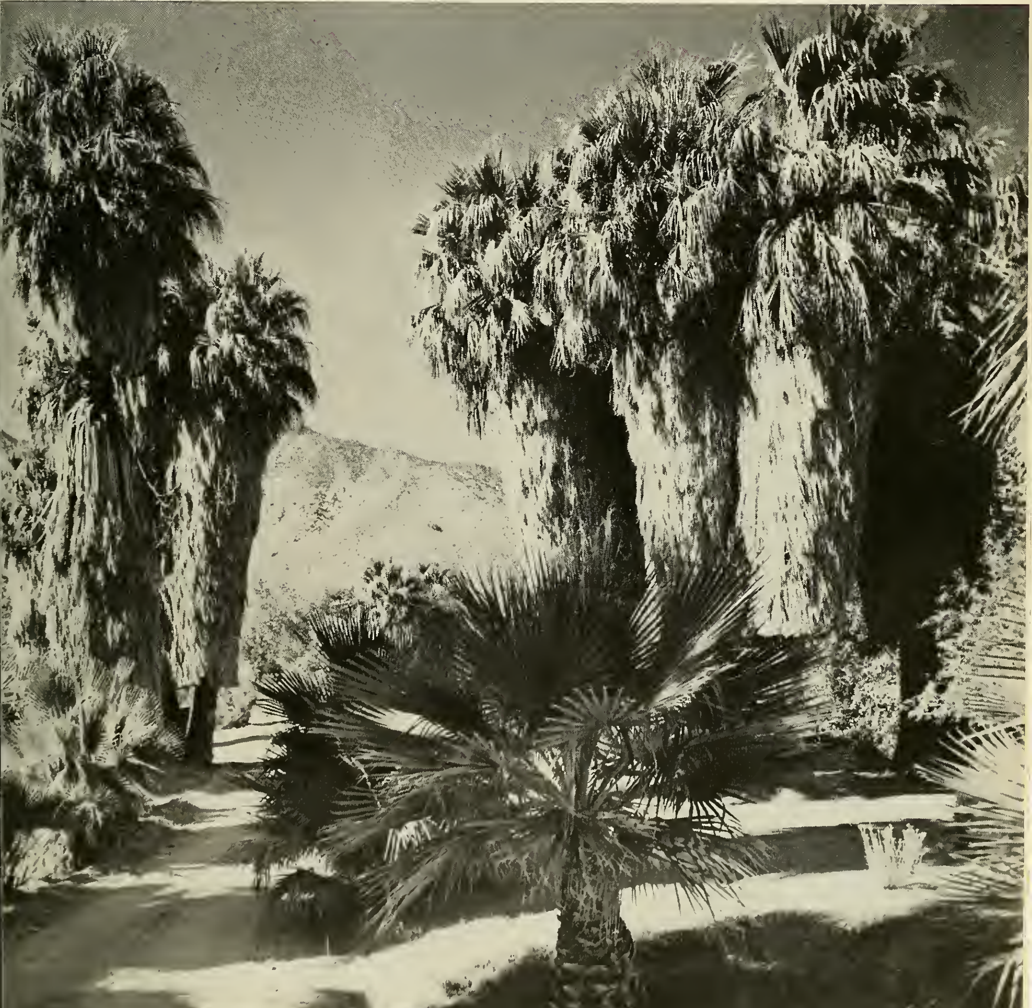
Both the age of the oldest and their unknown history provide the palms with an aura of mystery. No one has yet determined how old the trees are, for these monocots lack a cambium and hence have no annual rings. Another area of interest lies in their discontinuous distribution, for the scattered groves suggest that they once had a connected distribution pattern under a more beneficent climate. Verifications of this feature and of the

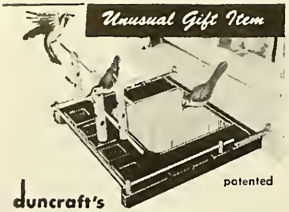
trees' ages await further investigation.

Probably no other area of comparable size anywhere in the world possesses so many rare and interesting trees as the state of California. Here are found the world's tallest, bulkiest, oldest, and probably rarest trees. All are in magnificent natural settings and, fortunately, some of each grow on publicly owned and managed land. But all are accessible to the automobile. With today's growing population and vastly increased mobility, such biological phenomena will receive increasing numbers of visitors. Seen they must and should be, for their value to man is immeasurable.

But this unusual environmental force—man—also creates vast changes so quickly that three lines of activity have been urged. First, much more of our flora and fauna—not alone these unusual trees—must be preserved in parks and wilderness areas for future enjoyment and study. Second, active research into the historical development and ecological relations of many of these plants is needed before changes brought about by fire protection and increased human use make such studies difficult. Third, aided by the knowledge gleaned from such research, active management—not a "locked gate" policy—may be needed to insure their future.

Desert fan palm shows thatch effect of dead fronds on trunks. The greatest threat to continued existence of trees is extreme flammability of this thatch.





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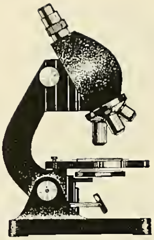


NATURE and the MICROSCOPE

The world of the protozoans

By Julian D. Corrington

The town of Delft, in the Netherlands, is particularly famous for two things: one is the celebrated blue or brown pottery covered with figures in white glaze; the other is Antony van Leeuwenhoek. It was Leeuwenhoek who, in 1675, introduced to a startled scientific public the world of the infinitely little—of the microscopic animals and plants. This great Dutch amateur microscopist drew and described a one-celled animal now known as *Vorticella*, and many of his subsequent discoveries of these creatures were so accurately depicted that they may be identified today as to genus or even species.

The huge Dutchman, with hams of hands, contrived to grind minute lenses and mount some of them in metal plates, therewith opening up the whole of the microcosmic world. He discovered bacteria, spermatozoa, yeast, red blood corpuscles, the construction of muscle, bone, and other body tissues, and a host of additional subjects.

Today, Leeuwenhoek's discovery of *Vorticella* and others of his "little animals," has blossomed into the important science of protozoology. There are some twenty-one major divisions of the animal kingdom, and the lowest of these is the Phylum Protozoa, consisting of those animals whose whole body is but a single cell, or sometimes a colony of cells. At one time, zoology stressed the simplicity of the Protozoa; now one speaks of their complexity, for some of them, as *Paramecium*, exist as single cells that are far more elaborate than any cell of the human body. For instance, in an individual animal, such as the *Amoeba*, a single cell with a nucleus and not much more, can do all of the basic things that a man can do! It moves about; it examines prospective food particles, accepting some and rejecting others; it digests these and uses the energy thus acquired for its own purposes; it avoids harmful objects in its environment; it respires, excretes, and reproduces.

The microscopist finds in this field one of his most important chapters. After classification has been mastered and some dozen or so forms known to the point of familiarity, a study of their lives, behavior, and habits may be undertaken, with experiments on their physiology.

Inevitably, their classification must come first. Protozoans are broken down into four classes, based on the structures they develop for locomotion. There may be protrusions of the cell substance, blunt or fine, known as pseudopodia (false-feet), which flow out, pull the animal forward, and then melt back into the general cell cytoplasm. They are temporary and are put forth now here and now there; some of them fork or branch and make a network with their neighbors. Protozoans that possess pseudopodia are members of the Class Sarcodina (sarcode means flesh), and the familiar example is amoeba.

Many protozoans are provided with one, two, or a few long whiplike processes, the flagella. Each is an extension, usually from the forward end of the cell; a fiber covered with a thin sheath. Flagellum means "little whip," and that is just what they are, as their vibrating movement results in pulling the animal forward in a straight line, an undulating line, or a spiral. Protozoa equipped with these structures are known as flagellates and belong to the Class Mastigophora (whip-bearers). The classic example for study is *Euglena*, but because this organism contains chlorophyll it is claimed by the botanists as a one-celled plant. The fact is that many of the first plants, as well as the first animals, progressed by means of flagella.

Most highly specialized of locomotor organelles in the protozoa are the cilia, and animals having these are called ciliates. An example is *Paramecium*, of the Class Ciliophora (cilia-bearers). The word comes from the Latin for eyelash, because the cilia are fine, hairlike processes that either cover the entire cell surface, or emerge from certain restricted areas. They beat in unison with an effective stroke and a non-effective stroke, as when oars are used to row a boat. In this class are the most highly diversified and interesting of all protozoa.

A fourth group, the Class Sporozoa, are all internal parasites. They have no organelles for locomotion. The malarial parasite, *Plasmodium*, is the most widely studied example. However, the beginner confines his attention mainly to the first three types of Protozoa, since study of the Sporozoa is an advanced topic.

The collecting of protozoans differs from that of most other animals or plants in that you cannot see what you are getting. The collector needs a number of large vials or small, wide-mouthed bottles, carried afield in a haversack or compartment belt. Bulkier but equally serviceable are pint Mason jars or half-pint and pint milk bottles. Paste a blank label on each container on which to record the date and place where the contents were gathered. Almost any body of water, large or small, transient or permanent, city or country, may be selected as a likely site: the ocean, lakes, rivers, ponds, brooks, pasture rills, hog wallows, or water standing in tree boles, ruts, or the urns sometimes seen on gateposts or in cemeteries. Submerge the unstoppered bottle, and with the fingers poke in a quantity of muck, leaves, green scum (algae), and other water plants so that the container holds about one-fourth solid materials and the rest water. Use the lid of the jar or a discarded photo film as a scoop to include thin layers of the bottom sediment or surface scum. Water-lily pads are a good source for amoebas and their cohorts. If you can break through the ice near shore with a hatchet, you will be able to collect protozoans even in winter.

Back at the laboratory or your worktable, remove the lids and place the bottles on a window ledge or table where they will stand in moderate or diluted sunlight; too much direct sun will overheat the water and kill the organisms.

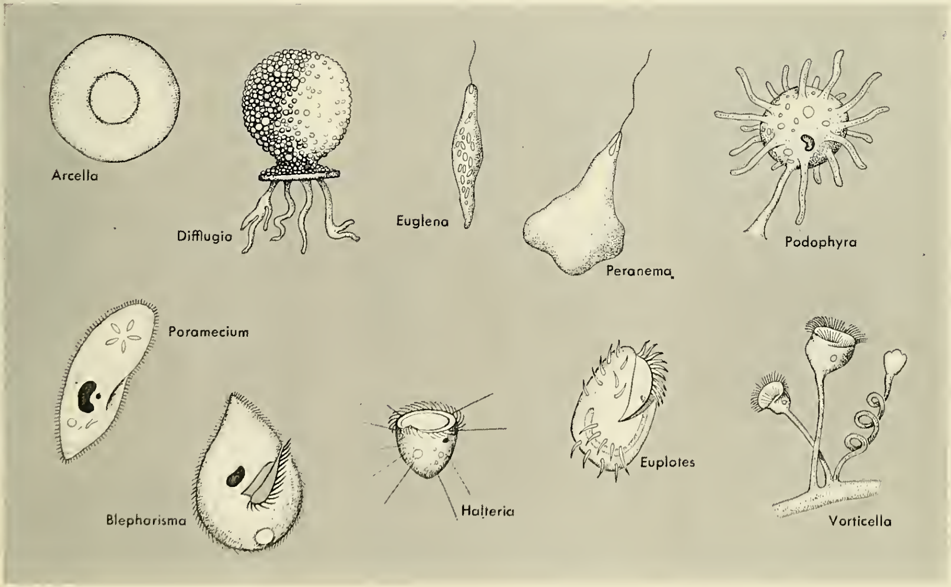
Dr. Corrington's column appeared regularly in Nature Magazine for nearly twenty years, and can now be followed in the combined magazines.

Each jar is now called a "culture"—by extension from the use of this word in propagating colonies of bacteria. The water level can be recorded either by affixing a label on the outside of the container so that its top edge is flush with the level, or by using a glass-writing pencil. From time to time, as may appear necessary, add some of the same kind of water from which the original collection was made, to maintain this approximate level.

Begin a hay-infusion microcosm as follows: use a battery jar or other tall, straight-sided receptacle and fill it almost to the top with tap water. Allow it to stand uncovered for two days to permit the evaporation of excess dissolved oxygen in the water, then put in a generous handful of hay. Any kind will do, but timothy is preferred. Add a glass plate as a lid and stand this jar on the window ledge, as with your other collections. Keep a record of dates when begun, when ended, and for each examination in between, with lists of the organisms identified together with information on their rise, flowering, and decline. A similar preparation using lettuce is also good. After a few days these infusions will be teeming with many forms of life.

You will need one or more collecting tubes, which are rather like glorified medicine droppers. They may be purchased, but are simple to make. Take a length of glass tubing about the diameter of a medicine dropper, draw the center out in a flame to make a constriction, file a nick across the middle of this narrow part, break off and anneal the break. Equip a one-foot length of such a tube with a rubber bulb about the size of a ping-pong ball. This is now a long-barreled pipette of the medicine dropper type that can reach to the bottom of your tallest culture and infusion vessels.

Take samplings of a few drops from the top surface of each vessel for one group of slides; from an inch below the top for another; and from the surface of the bottom sediment for a third. In each case, place one large drop on the center of a clean, blank slide and cap with a cover glass. Allow the cover glass to fall gently into place so the water can spread out beneath it to fill the whole area and thus float the cover. After a minute or two, the microscopic animals will recover from this rude transfer in their surroundings and will resume activity. First examine the slide under a low-power and then under a high-power objective, cutting down the light so that glare does not drown out the images. Some kinds of protozoans, as the amoebas and slower flagellates, may be kept under observation continuously, even under high power, but the swift forms dash about so rapidly that some means of quieting them is essential.



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WITHIN an average time of about thirty minutes, evaporation of the water from around the edges of the cover glass will have pulled the cover down upon the organisms, crushing them. As this is occurring there comes a time when their movements are so restricted that even the fastest among them will no longer be able to move and can be studied in detail under high power. To prevent their loss through crushing you may use an ordinary medicine dropper pipette to add a drop of the culture water exactly at the edge of the cover. The water will be drawn under by capillarity and rejuvenate the slide—but be careful that no water gets on the top of the cover.

You may decide to wash up this preparation and make a fresh slide. A better method is to use one drop of a 10 per cent fully hydrolyzed solution of polyvinyl alcohol or one drop of methyl cellulose (trade name Methocel), either of which may be obtained from a biological supply house. To one drop of culture add one drop of "quieter," mix thoroughly with a toothpick, then add the cover. These chemicals have a high viscosity, which impedes the progression of the protozoans without harming them. Another method is to place on a slide a ring of Methocel smaller in diameter than the cover. Place a drop of culture within this ring, then add the cover. The quieter gradually diffuses into the culture, bringing on a progressive slowing down of the animals. While such a slide is being prepared, especially if the ciliate *Paramecium* is to be studied, you may also add a speck of finely ground or powdered carmine (rouge is a good source). The bright red particles will be ingested along with bacteria upon which the paramecium feeds, and the entire process of formation of food vacuoles and their circular movement round the cell (cyclosis) as digestion proceeds to a final elimination can be followed.

These cultures run through cycles. At one time the flagellates are dominant, later the ciliates; or one kind of ciliate is dominant, then another. A culture that appears to be dying out can be rejuvenated by adding new sources of food. For example, a number of investigators advocate using about one-tenth of a tablet of malted milk, mashed until powdered, then sprinkled on the surface. This brings about a rapid growth of bacteria, on which the paramecia and other protozoans will feed. Or add some strong boiled hay infusion of a dark brown color or a small amount of mashed yeast cake. The appearance of numbers of rotifers in an infusion is a sign that the microcosm is running down. These multicellular creatures are so interesting that we shall devote an article to them.

You will need a manual for identification, and one of the best is *How to Know the Protozoa*, by T.L. and F.F. Jahn, Wm. C. Brown Co., Dubuque, Iowa, 1949. One of the best general textbooks on the subject is *Protozoology* by R. P. Hall, Prentice-Hall, Inc., N.Y., 1953. Collecting, mounting, staining, and studying methods are described in the writer's *Exploring With Your Microscope*, McGraw-Hill Book Co., Inc., N.Y., 1957, illustrated with those species most likely to be encountered.

SARCODINIANS commonly observed in fresh-water cultures include the famous *Amoeba*, which is large as average protozoans go, filling the field under high dry (430X). It is colorless and appears as an irregular blob of jelly, flowing slowly along and putting forth pseudopodia, into which the protoplasm of the cell streams as it goes. *Arcella* resembles a doughnut in front view, a football from the side, and is brown in color. This is because it is a shelled amoeba, with a circular opening in the lower surface through which it puts out pseudopodia. *Difflugia* is another shelled form, with a case made of sand grains cemented together in the shape of a helmet, the pseudopodia projecting from the circular opening in the bottom.

Among flagellates, there is *Peranema*, a plastic little animal that spends much of its time changing its shape from triangular to oval to elongate. This cell moves forward in a straight line very slowly, stops and changes shape, then resumes locomotion again. It has two flagella, though only one is evident, the other being trailing and small. The observer will be mystified in that the main flagellum does not appear to vibrate, so that the animal progresses by no discernible means. Under high power with the light very dim, or with dark-field or phase-contrast techniques, it may be seen that only the tip of this flagellum is moving, vibrating rapidly—noted by flashes of light—and effecting forward movement.

Astasia is a favorite specimen in the Class Mastigophora. It is a pear-shaped cell that moves forward steadily and slowly. It also has two flagella, the trailing one seldom seen, the other quite evident, long, and in active motion. *Euglena* is small, spindle-shaped, and much more rapid in locomotion than the two preceding. It is often present in enormous numbers, its bright green color making whole ponds or ditches green. The single flagellum is difficult to see. In dim light and under high power, the movements of this little whip will be evidenced by flashes of light. At times the cell stops swimming, turns and coils upon itself, changing shape. The series of acts is termed euglenoid movement. At or near the base of the flagellum is a bright red eyespot, sensitive to light. The bulk of the cell is filled with chloroplasts—small bodies containing bright green chlorophyll, a word that means "green leaf." Chlorophyll is one of the most remarkable substances in the world. In the presence of sunlight as a source of energy, this pigment is able to synthesize carbohydrates from carbon dioxide and water. It is the primary manufacturing process for all foods of plants and hence, eventually, of animals. Because of their chlorophyll content, these protozoans will orient themselves with relation to light. If one side of the cover glass is made dark and the other side is brightly illuminated, the euglenids will all gather in a band across the center, where the light is of proper intensity for photosynthesis to take place.

THE microscopist finds his interest in the protozoa at its height, however, when he examines the ciliates, for they are an immense and diverse group whose members exhibit the greatest amount of specialization of which a single cell is capable. In the Class Ciliophora there are two main divisions, the Suctorea and the Ciliata. Suctoreans possess cilia only in the early stages of their life cycle. As adults they develop sucking tentacles, which they attach to the bodies of their ciliate victims, holding them fast in their struggles. These tentacles are hollow, and through them the cell substance of the prey is sucked. All members are attached to some object in the substrate and most of them are stalked. Commonest is *Podophyra*, frequent in fresh-water cultures, which looks like an animated pincushion on a stalk.

Ciliates were formerly termed Infusoria, since they are so abundant in infusions. *Paramecium* belongs to the Order Holotrichida, known as holotrichs, in allusion to their possession of cilia of more or less uniform length and size over the whole cell surface. The *Paramecium* is the Slipper Animal, referring to its shape, and is widely studied in all biology and zoology courses. It contains a macronucleus and one or more micronuclei, two contractile vacuoles—one in each half of the elongate cell—and a gullet in which an undulating membrane may be seen vibrating rapidly, driving food particles from the external mouth into the interior of the animal.

Other holotrichs likely to be encountered include *Frontonia*, which looks like a large and robust paramecium without the middle constriction; *Colpidium*, about the size of a paramecium, but with the anterior end permanently bent at an angle, and often appearing in immense numbers in a hay infusion; *Colpoda*, small, kidney-shaped, with the mouth notched in the concave side; *Didinium*, the Paramecium Tiger, resembling a miniature turtle and, though smaller than its victim, it attacks paramecium and sucks the whole cell in through its terminal mouth; *Spathid-*

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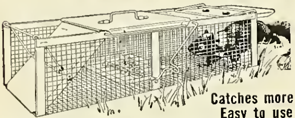

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ium, also a predator, medium to large, with a terminal mouth and a vase-shaped body; *Coleps*, barrel-shaped, medium in size, terminal mouth, which looks armored, with numerous plates arranged in a geometric pattern; *Lacrymaria*, the Swan Animal, a very large ciliate, with the mouth at the apex of a long "neck" that can be thrashed about vigorously; and *Dileptus*, also large and with a long "neck," but with the mouth at its base instead of its terminus.

From the holotrichs, evolutionary progression among the ciliates took either of several lines of development. The heterotrichs are those that possess cilia all over the body and, in addition, fused rows of cilia (membranelles) arranged one behind another like little paddles, in a zone near the mouth. These serve to propel food particles toward the mouth opening. Four well-known genera are *Blepharisma*, which, of all things to encounter among protozoans, is pink in color and has somewhat the size and shape of paramecium; *Spirostomum* is a giant among one-celled organisms, attaining a length as great as 3 mm. It is elongate, pencil-shaped, with a single, huge rear contractile vacuole: *Bursaria*, the Purse Animal, very large indeed, vase-shaped, highly carnivorous, and capable of devouring many paramecia; *Stentor*, the Trumpet Animal, amazingly dark blue in color, very large, usually attached by a short stalk but capable of breaking away and swimming off.

Hypotrichs have a mouth zone of membranelles and usually a number of ventral cirri. These are tufts of cilia that fuse to make a fairly stiff structure, almost like a spine. The cirri are used like legs, and these little animals run rapidly over the surface of some submerged object or other animal, such as hydra. *Stylonychia*, the best-known genus, reminds one of a microscopic bug as it scampers along a strand of alga. The bottom surface of this ciliate is flat, the top arched, the outline somewhat oval, but widened posteriorly, ending in three tail cirri that project like bristles. The size is that of a paramecium or smaller. *Oxytrichia* is similar, but lacks the caudal bristles; *Euplotes* is shorter, smaller, rounder, and the cirri are very large; *Uroleptus* is elongate and has the ventral cirri in rows.

Least abundant of ciliates are the oligotrichs. They have the same mouth zone as the foregoing, but the ciliation elsewhere is greatly reduced or absent. The only form likely to be seen is *Halteria*, indeed a curious protozoan. It is a small and roundish cell, with a belt of cirri around the middle, but the principal feature that will attract attention is its means of locomotion—it springs from place to place in sudden leaps.

Peritrichs are commonly bell- or vase-shaped, and attached to some object by a stalk. They have a mouth zone of semi-membranes that beat counterclockwise and drive food down the gullet. Body ciliation is sparse or absent. *Vorticella*, described by Leeuwenhoek, is the best-known type. These are social animals, numbers of them being found together. The cell is vase-shaped, on a long stalk that contracts when disturbed, coiling like a watchspring, then slowly expanding if unmolested. *Epistylis* is colonial, the common stalk branching and with an individual at the end of each branch.

In a later installment we shall take up the parasitic protozoa, which form a fascinating introduction to parasitology.

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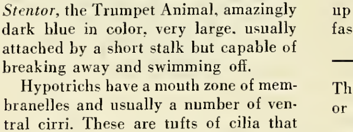

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